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TOMATO DISEASES and Their Control

Agriculture Handbook No. 203

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TOMATO DISEASES
and Their Control

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Tomatoes are one of the most important and widely distributed vegetable crops in the United States. From 1950 to 1959, the average yearly planting of tomatoes was more than 550,000 acres. The average estimated farm value of the crop was approximately $227 million.[2] Wherever tomatoes are grown, diseases seriously reduce both the yield and the market value of the fruit.

TYPES OF DISEASES

Tomato diseases are of two general types—parasitic and nonparasitic.

Parasitic diseases are those caused by living organisms, chiefly bacteria and fungi, and by viruses. The parasitic group includes most of the common and serious tomato diseases.

Nonparasitic diseases are caused by unfavorable environmental conditions, such as excessive moisture or drought, extremes of temperature, and lack or excess of certain mineral elements in the soil.

Bacteria and fungi are microscopic organisms that obtain their food from the plant they attack or from decaying organic matter in the soil. They enter the plant through wounds and natural openings or directly penetrate the epidermis. After entering the plant, they multiply within the plant tissues and produce specific symptoms, such as wilting of the plant, spotting or curling of the leaves, and decay of the fruits.

The bacteria affecting tomatoes are one-celled, rod-shaped organisms that multiply with great rapidity in the plant. They occur on the surface of diseased plants either as exudates or as the result of a breaking open of the diseased tissue and, when so exposed, are readily spread to other plants by splashing rain, insects, or human beings.

The fungi are more complex organisms with threadlike vegetative growth (mycelia) from which are usually produced various types of structures that bear seedlike bodies known as spores. In the presence

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[1] Retired; died Aug. 9, 1961.

[2] U.S. Department of Agriculture, Agricultural Statistics 1950–59.

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of moisture these spores can germinate and produce new infections. They are spread by wind, rain, drainage water, insects, and persons working among the plants.

Since the bacteria and fungi are living organisms, they are destructive only when environmental conditions, particularly temperature and moisture, are favorable to their development and spread. Because tomatoes are grown under various environmental conditions, the diseases of most importance in one region may be almost unknown in another.

Plant viruses are complex protein substances that increase rapidly in the plant. The individual virus elements are too small to be visible except under the electron microscope. Viruses are highly infectious, and many of them are readily transmitted by any means that serve to introduce a minute amount of juice from a virus-infected plant into a slight wound or abrasion in a healthy one.

The most common means of transmitting virus diseases are sucking insects, particularly aphids, and the brushing against, handling, or pruning first of diseased and then of healthy plants. Some viruses, such as the ones causing curly top and spotted wilt, however, are transmitted by only certain species of insects and are not spread by contact with the plants. Such diseases are serious only in regions where conditions permit the existence of the insect carriers in large numbers. A few viruses are transmitted in the seed of certain of their host plants, but such transmission is comparatively rare. Most viruses do not survive in the soil, but a few do. Certain viruses, though much alike in their chemical and physical properties, do not produce exactly the same symptoms on all species of plants. Such viruses are known as strains of a single virus.

Ordinarily, a diseased plant cannot be cured; therefore, control must be based on the prevention of the disease and of its spread . Many tomato diseases are not readily controlled after they are once well established in the field or greenhouse, but it is often possible to limit their occurrence by preventing infection from contaminated seed and soil or from weeds that carry disease-producing organisms or viruses. When disease-free plants are set in clean soil, the likelihood of serious losses is greatly reduced.

This handbook describes the diseases commonly affecting tomatoes in the field and greenhouse and gives measures recommended for reducing losses from them. As the methods of control vary with the nature and cause of the individual disease, it usually is necessary to determine what particular disease is responsible for an injury before applying control measures. An accurate diagnosis (see key, p. 82) is necessary to prevent waste of time and materials. Often a careful examination of the leaves, stems, and roots is required to be sure that the disease is diagnosed correctly. Many diseases are easily recognized, but others may be hard to identify. When there is any question as to the diagnosis, it is best to consult the local county agricultural agent or send specimens to the State agricultural college.

DISEASES CAUSED BY BACTERIA AND FUNGI

Fusarium Wilt

Fusarium wilt, caused by the fungus *Fusarium oxysporum* f. *lycopersici* (Sacc.) Snyder & Hansen, is one of the most prevalent and damaging diseases of tomatoes in many of the tomato-growing regions of the United States. The fungus causing the disease affects only the cultivated tomato and certain wild tomato species. It is soilborne and is found in both field and greenhouse soils. The organism generally does not cause serious losses unless soil and air temperatures are rather high during much of the season. Where such conditions prevail, plants of susceptible varieties either are killed or severely damaged when grown in infested soil.

In seedling plants fusarium wilt causes drooping and downward curvature of the oldest leaves, usually followed by wilting and death of the plant. Older plants in the field are infected at all stages of growth, but the disease generally becomes most evident when the plant is beginning to mature its fruit. The earliest symptom is yellowing of the lower leaves. Often the leaves on only one side of the stem turn yellow at first; also the leaflets on one side of the petiole may be affected before the others. The yellowed leaves gradually wilt and die and, as the disease progresses, yellowing and wilting continue up the stem until the foliage is killed and the stem dies. Frequently a single shoot is killed before the rest of the plant shows much injury (fig. 1). The stem of a wilted plant shows no soft decay, but, if it is cut lengthwise, the woody part next to the green outer cortex shows a dark-brown discoloration of the water-conducting tissues (xylem); this is characteristic of the disease and helps in its identification (fig. 2). This discoloration often extends upward for some distance and is especially evident in the petioles of wilted leaves at the point where they join the stem.

At times the same type of discoloration may be seen also in the water-conducting vessels in the central part of the fruit, but this is

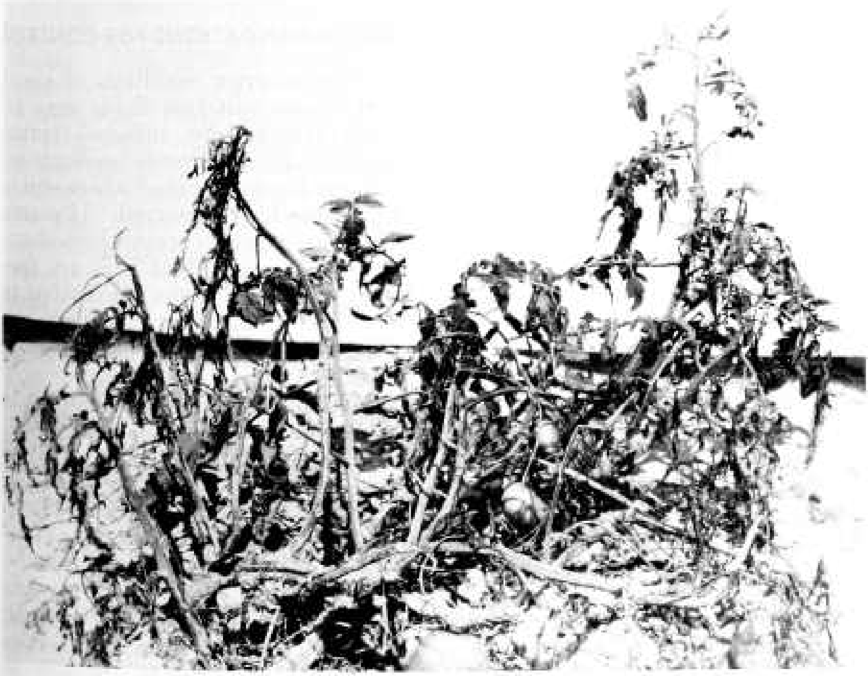
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Figure 1.—Tomato plant showing symptoms of fusarium wilt. Some shoots have been killed, but others show only drooping leaves.

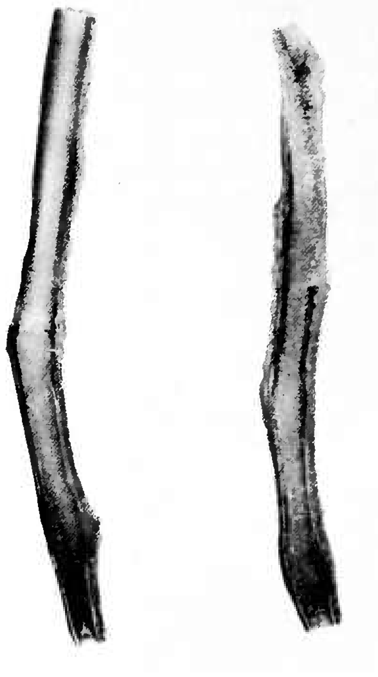

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FIGURE 2.—Stems of tomato plants affected with fusarium wilt split lengthwise to show the discolored line of woody tissue between the pith and the outer green part of the stem.

less common than in the stem and leaves. The fruits are not spotted.

The fungus causing fusarium wilt enters through the roots and passes upward into the xylem of the stem. Here it apparently produces toxic substances that discolor and partially block the vascular bundles. The reduced flow of water possibly is the chief cause of the wilt, but toxic materials also may cause increased water loss from the leaves and other effects that contribute to the wilting and death of the plant.

Occasionally the fungus may pass into the fruits and penetrate the seed. However, infection from such seed is probably rare, as infected fruits usually decay and drop. If infected fruits are harvested, their seed are usually so light that they are eliminated in the extraction and cleaning of the seed. Spores may occur on the surface of the seed; but, if a surface disinfectant is used, there is little danger of infection from this source. Nearly all infection can be traced to seedbed or field soil, but seed may occasionally be responsible for the appearance of the disease in a new locality.

The fungus may become established in many types of soil, but it is likely to cause the most damage on light, sandy soils. It is most active at temperatures between 80° and 90° F. Where conditions are favorable to its growth, it can live almost indefinitely in the soil even when no tomatoes are grown. Previously clean fields may be infested by the use of infected transplants or by windborne or water-washed soil, farm implements, or any agency that carries small amounts of infested soil.

RECOMMENDATIONS FOR CONTROL

Always grow seedlings on clean soil, since wilt-free fields may be contaminated by infected transplants. Do not locate seedbeds on old garden soil or land where wilt is known to have occurred. If plants are purchased, obtain them from growers whose plant beds are free from the wilt fungus. It is safest to purchase plants that have been certified by State agencies as free from disease.

When the disease has occurred in the greenhouse or in hotbeds, sterilize the soil by steaming (p. 73) or treating it with one of the chemical disinfectants (p. 74). Treat seedbeds in the same manner. However, treatment of field soil is usually too expensive. If the fungus becomes established in the field, practicable rotations are ineffective because the organism persists so long.

Use of resistant varieties will prevent losses from fusarium wilt.

Several of these varieties remain uninjured even when grown at high temperatures on soil heavily infested with the wilt fungus. Varieties with this high resistance are available for processing or fresh-market production in all the tomato-growing regions of the United States.

Some of the more widely grown, red-fruited resistant varieties are Campbell 146, Homestead, Kokomo, Manalucie, CPC–2, Pearson VF–6, and Pearson VF–11. The last three varieties, developed for use in California and adjacent States, also are resistant to verticillium wilt (p. 6).

Resistant varieties for special uses include: Roma, whose pear-shaped fruits are used for paste and whole-pack processing; Sunray, a large-fruited, yellow variety; and Pinkshipper, developed for use where a pink tomato is desired for the fresh market.

Highly resistant varieties for greenhouse forcing include the pink varieties Ohio W–R7 and Ohio W–R Globe and the red varieties Michigan-Ohio Hybrid and Tippecanoe.

Some other varieties that do not have the high resistance of those just mentioned are often sufficiently resistant to produce profitable crops where completely susceptible varieties fail. However, these so-called tolerant varieties may suffer severely from wilt when conditions are very favorable to its development. Some of them are widely used in areas where losses from wilt are not generally severe. This group includes Rutgers, Improved Garden State, Improved Urbana, Marglobe, Pritchard, Sioux, Stokesdale, Big Boy, and Redtop VR–9, which also is resistant to verticillium wilt. Michigan State Forcing is a wilt-tolerant greenhouse variety.

Verticillium Wilt

Verticillium wilt, caused by the fungus *Verticillium albo-atrum* Reinke & Berthold, attacks a wide range of plants. Tomato, potato, eggplant, and okra are the vegetables most commonly affected. On tomatoes, the symptoms may be confused with those of fusarium wilt. The disease causes serious losses of tomatoes in some sections of California and in Utah. Occasional losses occur in some North Central and Northeastern States, but the disease is rare in the South. In the greenhouse it sometimes causes some damage when the soil is not sterilized frequently.

The first symptom is yellowing of the older leaves, accompanied by a slight wilting of the tips of the shoots during the day. The older, yellowed leaves gradually wither and drop, and eventually the crown of the plant is defoliated. The leaves higher up the stem become dull looking, and the leaflets tend to curl upward at the margin. All branches are uniformly affected and have a tendency to be less erect than those of healthy plants. The plants usually live through the season but are somewhat stunted, and the fruits are small. In late stages of the disease, only the leaves near the tips of the branches remain alive. The loss of the lower leaves and the stunting of the later growth expose the fruit to the sun, and much of the crop is often lost because of sunscald (fig. 3).

When the stem is cut lengthwise, the base shows a discoloration of the woody tissues much like that caused by fusarium wilt. At times the discoloration is darker than that caused by fusarium wilt, and generally it occurs only in the lower part of the stem. No soft decay of the stem and no spotting of the fruit are present.

Tomato leaves sometimes are infected by spores of the fungus. Such leaves show yellow areas at the margins of the leaflets. These become V-shaped; the yellow tissue gradually dies; and severely in-

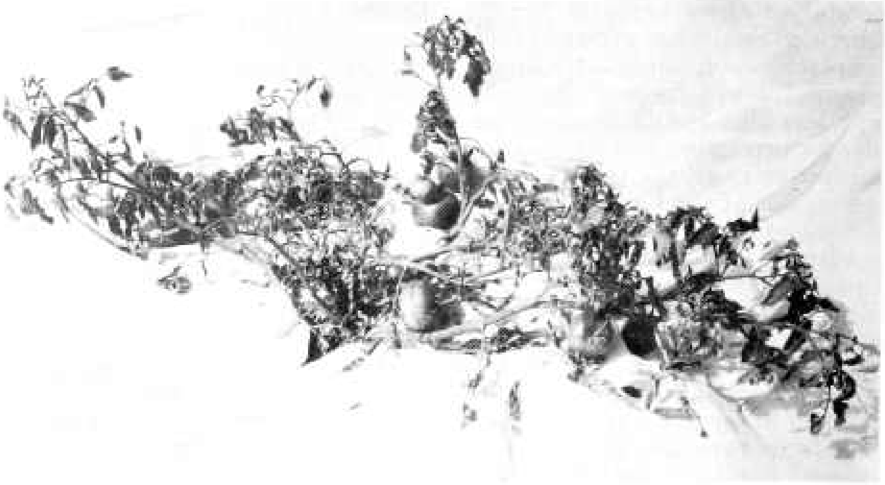

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FIGURE 3.—Tomato plant affected with verticillium wilt. The branches tend to lie close to the ground and the crown of the plant is open to the sun.

fected leaves may eventually drop. The fungus invades the vascular system of the leaf and apparently may cause systematic infection of some plants.

Fusarium and verticillium wilts may occur in the same field and at times are hard to distinguish. Typical cases of fusarium wilt can be distinguished by the yellowing of leaves on single branches and the more frequent wilting and death of plants before the end of the season.

The fungus causing verticillium wilt can live for a long time in the soil, and soil reaction has little to do with its persistence. Seed may be infected, but this apparently is rare; infection almost always results from the presence of the fungus in the soil. The organism enters the plant through the roots and invades the xylem tissues of the stem. In late stages of the disease, the fungus enters other tissues of the stem. The progress of the disease is favored by temperatures of 70° to 75° F. and retarded by the higher temperatures that are most favorable to fusarium wilt.

RECOMMENDATIONS FOR CONTROL

Locate seedbeds on soil free from the fungus. If this cannot be done, disinfect the soil by steam (p. 73) or treat it with chloropicrin (p. 74) or methyl bromide (p. 75). The varieties VR Moscow, Loran Blood, and Redtop VR–9 are resistant to verticillium wilt. Pearson VF–6, Pearson VF–11, and CPC–2 are resistant to both verticillium and fusarium wilt (p. 5).

Bacterial Wilt

Bacterial wilt, or brown rot, caused by *Pseudomonas solanacearum* (E. F. Sm.) E. F. Sm., occurs most commonly on tomatoes in the Southern States, but occasionally it is also found in other tomato-growing regions. In the South, the disease causes considerable injury to potatoes, tobacco, and peppers and also attacks peanuts, eggplants, soybeans, and some other cultivated and wild plants. It is not generally serious on tomatoes, but it causes some damage in occasional fields.

The symptoms are rather rapid wilting and death of the entire

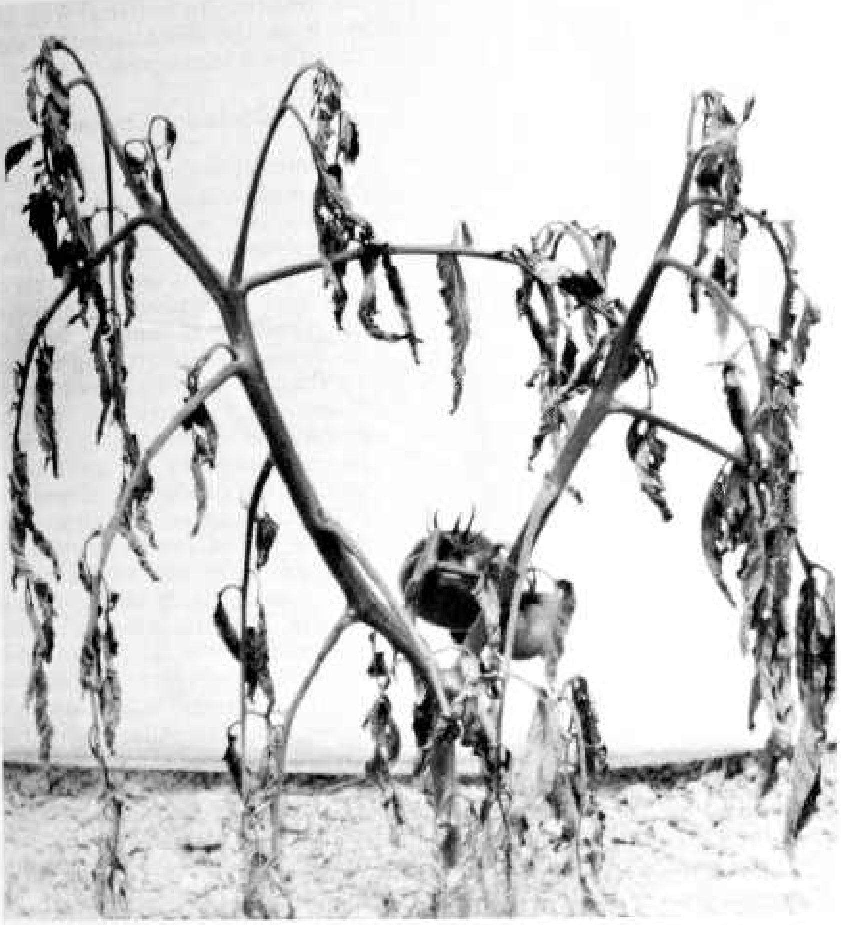

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FIGURE 4.—Tomato plant showing symptoms of bacterial wilt. All the branches have wilted at about the same time because of bacterial infection in the stem.

plant unaccompanied by any yellowing or spotting of the leaves (fig. 4). If the stem of a wilted plant is cut across near the ground, the pith has a darkened, water-soaked appearance and there is a grayish, slimy exudate when the stem is pressed. In later stages of the disease, decay of the pith may cause extensive hollowing of the stem (fig. 5). These symptoms differ from those of fusarium and verticillium wilts, which do not cause sudden wilting or decay of the stems of older plants. Bacterial wilt causes no spotting of the fruits.

The bacteria causing the disease live in the soil and infect the plants through the roots or stem. They move into the large vascular bundles and later cause a decay of the pith, which may produce large cavities in the stem. The wilting appears to be caused by a gradual blocking of the movement of water in the stem. The bacteria are most common in low, moist soils and are most active at temperatures above 75° F. They may occur on newly cleared land as well as on land that

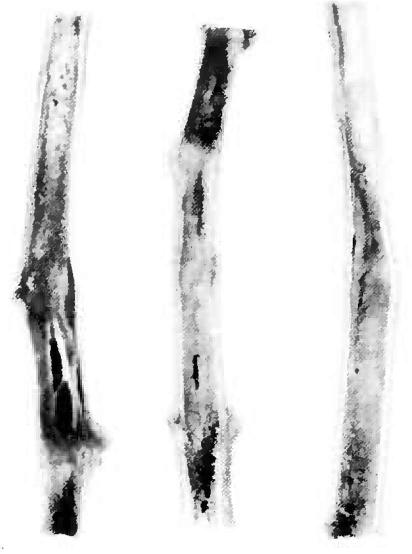

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FIGURE 5.—Stems of tomato plants affected with bacterial wilt split lengthwise to show the discoloration and soft decay of the pith. The decay is accompanied by a rapid wilting of the tops.

has previously grown susceptible crops. The disease is usually worst on light soils. Fields frequently are first infested by planting infected seedlings, which often show no evidence of the disease until they are transferred to the field. The bacteria also may be carried by drainage water from an adjacent field.

RECOMMENDATIONS FOR CONTROL

Do not grow seedlings in beds where the disease has occurred. If such beds must be used, disinfect them with chloropicrin (p. 74) or methyl bromide (p. 75). To prevent infection from drainage water, do not plant seedbeds or field plantings close to land where the disease was present in the previous year. Practice crop rotation (p. 67). If only a few wilted plants are found, remove them from the field at once to prevent further spread of the disease. No varieties of tomato now (1961) grown in the United States are resistant to bacterial wilt, but work on the development of such varieties is in progress.

Bacterial Canker

Bacterial canker is a destructive disease of tomatoes caused by *Corynebacterium michiganense* (E. F. Sm.) Jensen, a bacterium that may be carried by the seed. Because of this seed transmission, the disease has appeared at times in many of the major tomato-growing regions. In the past it often caused serious losses, particularly on canning crops; but these losses have been much reduced by the greater care used in the production of seed free from the canker organism. The disease is occasionally found in the greenhouse, as well as in the field, and attacks plants at any stage of growth. Natural infection has been observed only on the tomato except for a single plant of perennial nightshade found in a tomato field.

Frequently seedlings are infected; they may be rapidly destroyed or occasionally may show no signs of the disease until some time after being transplanted in the field. Wilting of the leaflets is the first symptom on plants of all sizes. On older plants the margins of the leaflets of the lower leaves wilt first. As the margins dry, the leaflets curl upward and inward (fig. 6, *A*). Later these leaves become brown and wither, but they remain attached to the stem (fig. 7). Usually only the leaflets on one side of the leaf are affected. The plant itself often shows a one-sided development of the disease that causes it to lie over in a characteristic way. A single shoot may be killed early, and the rest of the plant may appear normal for some time; but eventually the dying continues up the stem and much of the foliage is destroyed. Diseased plants may die early, but they commonly survive until harvest.

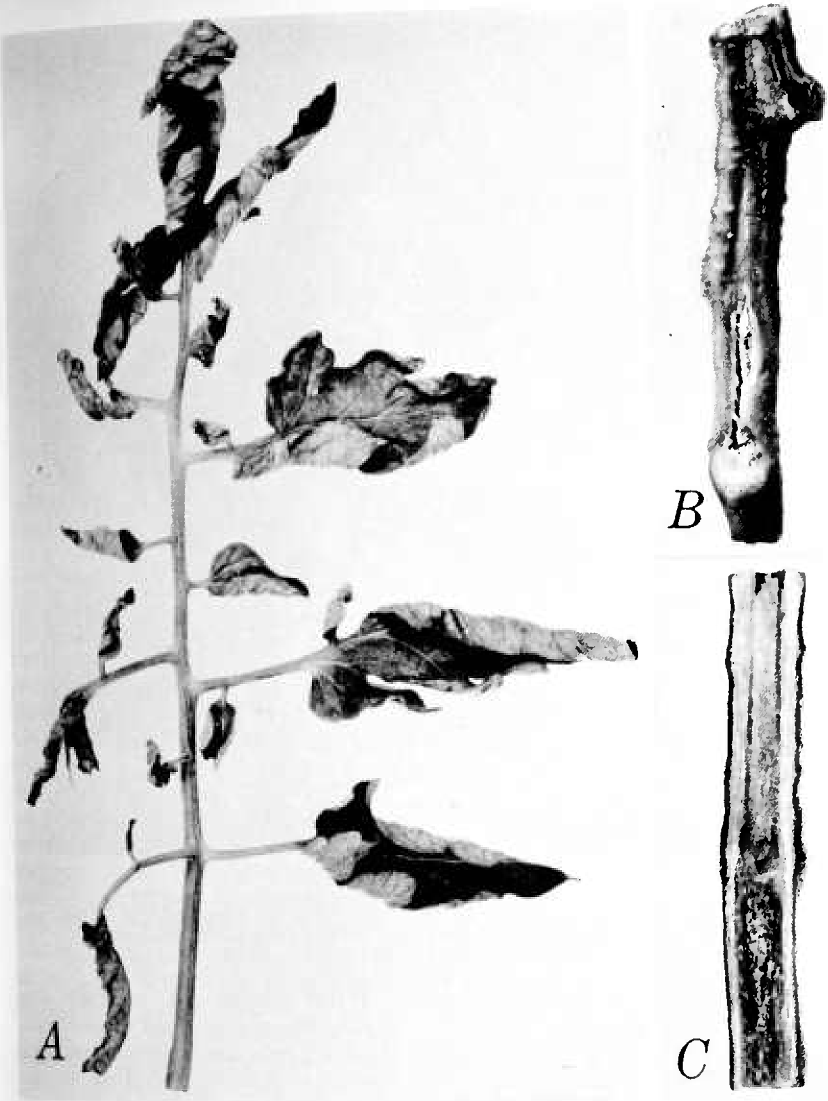

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FIGURE 6.—Stems and leaf of tomato plant affected with bacterial canker: *A*, Leaf showing curling and withering of leaflets; *B*, stem showing open canker; *C*, stem split lengthwise to show decay of the inner tissues.

The wilting of the leaves is accompanied by light-colored streaks that extend down the stem and along the underside of the petiole from the point where it joins the stem. These streaks later may break open at intervals and form the cankers that give the disease its name (fig. 6, *B*).

The bacteria first enter the vascular system, soon they are established and move in the phloem tissues, in which elaborated food materials move from the leaves to the stem. This organism is the only known vascular bacterial parasite that moves primarily in the phloem tissue. Eventually it also

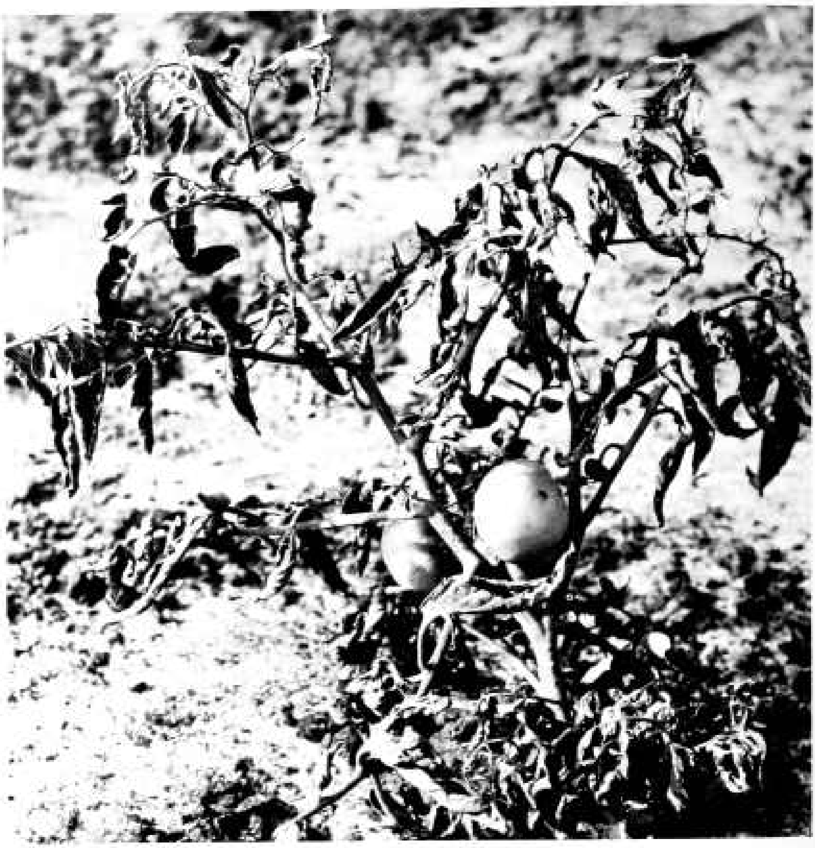

FIGURE 7.—Tomato plant attacked by bacterial canker. Many of the leaflets are curled and withered, but the petioles remain attached to the stem.

invades the pith and the cortex, or "bark," of the stem.

When the stem is cut lengthwise, there is a creamy white, yellow, or reddish-brown line just inside the woody tissue. The pith is easily separated from the woody elements along this line. As decay progresses, the pith becomes yellow and mealy in appearance and cavities are formed in the soft tissue (fig. 6, *C*). The discoloration of the pith and its ready separation from the woody tissue are a valuable means of identifying bacterial canker. The decay of the cortex and inner tissues of the stem lead to the development of the open stem cankers (fig. 6, *B*).

When plants are severely diseased, the bacteria may pass from the stem into the fruits through the vascular tissues. If this occurs when the fruits are small, they are stunted and deformed. Larger fruits often show no external evidence of infection, but small, dark cavities may be found in the centers of such fruits. When this occurs the bacteria may enter the tissues that become part of the seed. If this takes place early in the development of the seed, the seed is destroyed; but if the bacteria enter after the ovule is well developed, a viable seed that carries the canker bacteria may be produced.

Fruits often are infected on their

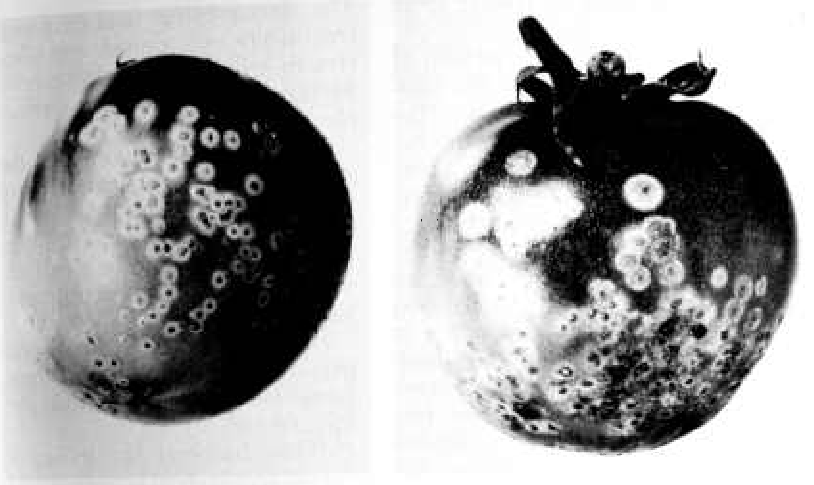

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FIGURE 8.—Tomatoes showing the bird's-eye spotting caused by the bacterial canker organism. The spots have dark, roughened centers and light, halolike margins.

surface by bacteria washed by rain from open cankers on the stems or leaves. These infections appear first as very small, snowy-white spots that do not extend deeply into the fruit. The margins of the spots remain white and flat; the centers become slightly raised, tan-colored, and roughened by slight breaks in the surface. These bird's-eye spots (fig. 8) are typical of the disease. The spots remain small—exclusive of the halo, they do not exceed one-eighth inch in diameter.

This halo is helpful in distinguishing canker spots from spots caused by bacterial spot (see fig. 21), but this character alone is not always a dependable means of diagnosis. In the early stage there is a greenish-white halo around the bacterial spot lesion that is not readily distinguished from that of the canker spot. However, the halo of the canker spot remains flat and white while that of the bacterial spot lesion is raised and disappears as the spot becomes older.

Contaminated seed frequently seems to be the source of primary infection by the canker bacteria. Some of this may be caused by internally infected seed, but this probably is less important than that caused by the presence of the organism on the seed surface. Surface contamination occurs when seed is extracted from fruits taken from fields where bacterial canker is present. When lodged on the surface of the seed, some of the bacteria may survive until the next season.

The organism can persist in seedbed and coldframe soils on remains of diseased plants from the preceding year. Seedling infection often can be traced to this source. The bacteria can persist in field soils for 2 to 3 years, but primary infection from this source seems to be rare.

RECOMMENDATIONS FOR CONTROL

Bacterial canker is unlikely to occur if clean seed is planted in clean soil. Make every effort to obtain seed from canker-free fields; it is much safer to use seed free from the canker organism than to depend on even the most efficient seed treatment. Therefore, when possible, use certified seed (p. 67) to avoid losses from bacterial canker.

If certified seed stock is not available, treat the seed to free it from the canker organism.

One method of freeing the seed of contaminated fruits from the canker bacteria is to ferment the crushed fruit pulp for 96 hours before extracting the seed. Thoroughly pulp the fruits before fermenting them. If it is possible to do so, run the fruits through some form of tomato juicer and then recombine the juice, pulp, and seed for fermenting. Never use water in place of tomato juice in this process, as this reduces the effectiveness of the treatment. Keep the fermenting pulp at an even temperature not much above or below 70° F. Higher temperatures increase the chemical activity of the fermenting pulp and may injure the vitality of the seed. Stir the fermenting material twice a day to submerge the pulp floating on the surface.

Another method is to soak the freshly extracted seed in an 0.8-percent solution of pure (U.S.P. grade) acetic acid in water. To prepare a solution closely approximating an 0.8-percent solution, add 1 fluid ounce of acetic acid to 1 gallon of water. Place the seed in a loosely woven cloth bag and immerse in the solution for 24 hours at an even temperature not much above or below 70° F. Thoroughly stir the solution to insure the wetting of all the seed. Treat only 1 pound of seed in 1 gallon of the solution.

Treat dried seed in a 0.6-percent solution of acetic acid. To prepare a solution closely approximating this, add three-fourths of an ounce of acetic acid to 1 gallon of water. Use the same precautions as to temperature as with freshly extracted seed. Immediately after treatment dry the seed at a moderate rate.

These treatments slightly reduce germination, but this is negligible if the directions about temperature are followed carefully. The fermentation and acid-soak treatments have proved very effective in killing both surface-carried bacteria and many of those within the seed.

Although it is known that the seed is from fields apparently free from bacterial canker, treat it with a chemical disinfectant (p. 70) to free the surface of the seed from any other disease-producing organisms.

Bacterial canker organisms can persist for a time in the soil; therefore, locate seedbeds with care (pp. 69 and 70).

When bacterial canker has occurred on plants in hotbeds or coldframes, if possible remove the soil to a depth of 10 inches and replace it with soil that has not grown tomatoes. Before replacing the soil, drench the subsoil and the frames and covers with formaldehyde (p. 75). Do this at least 3 weeks before planting. If the soil cannot be changed, disinfect with steam (p. 73) or a chemical disinfectant (p. 74). In the greenhouse, soil sterilization is necessary if the disease has appeared on the preceding crop. Steam sterilization is preferable, but if steam is not available treat the soil with chloropicrin or methyl bromide.

Southern Blight

The disease known as southern blight, or sclerotium rot, is caused by *Sclerotium rolfsii* Sacc. This fungus occurs to some extent throughout the southern United States; it is comparatively rare in other tomato-growing regions. It attacks many plants besides tomatoes, including beans, beets, cabbage, eggplants, peppers, potatoes, squash, sweetpotatoes, watermelons, and some ornamentals. On tomatoes the disease is not of major importance; it occasionally causes some loss.

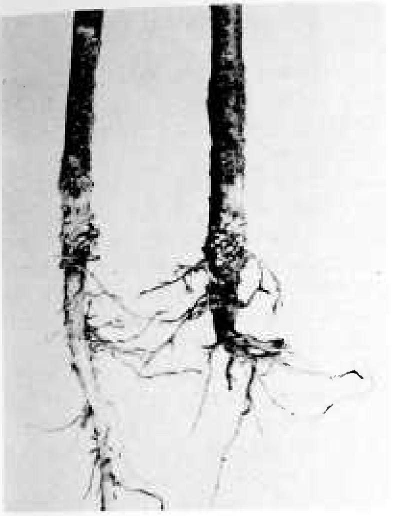

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FIGURE 9.—Roots and stems of tomato plants attacked by southern blight. Small, light-brown sclerotia on the stems are characteristic of the disease.

The first symptom on tomatoes is a general drooping of the leaves suggestive of bacterial or fusarium wilt. Wilting becomes more marked from day to day, and finally the plant dies without marked yellowing of the foliage. The stems show a brown decay of the outer tissues at the ground line. Frequently they are covered with a white fungus mat in which are embedded numerous small, light-brown bodies about the size of a cabbage or mustard seed (fig. 9). These are known as sclerotia and are characteristic of the disease.

The fungus also attacks the fruits where they touch the soil. It causes yellowed, slightly sunken areas that break open as the spots enlarge. The progress of the decay is rapid; the fruit soon collapses and is covered by a growth of the fungus.

The fungus makes little growth at temperatures below 68° F. and is, therefore, largely confined to the South. It requires abundant moisture for growth and is most prevalent on light, poorly drained soils. Apparently it produces no spores, but the threads of the fungus spread through the soil and the infested areas widen from year to year. It is also distributed by means of the sclerotia, which can live for some time in the soil and are spread by washing rains or during cultivation. Under favorable conditions these sclerotial bodies are able to put out new fungus threads and to cause further infection.

RECOMMENDATIONS FOR CONTROL

Sanitation is important in the control of southern blight. Where only an occasional plant is found, remove and burn it. This is most successful in small plantings, where all the plants can be readily watched for the presence of the disease. Rotating is important (p. 67). Do not locate seedbeds on land where southern blight has occurred within 3 years. If the disease has appeared in hotbeds or coldframes, sterilize the soil with formaldehyde (p. 75), chloropicrin (p. 74), or methyl bromide (p. 75).

Stem Rot

Stem rot, or sclerotiniose, is a disease of tomatoes that sometimes causes minor losses in the greenhouse and the field. It is caused by *Sclerotinia sclerotiorum* (Lib.) DBy., a fungus that frequently attacks beans, cabbage, celery, lettuce, potatoes, and some other vegetable crops. Tomatoes are rarely affected unless grown in soil where the disease has been common on other crops, and generally only an occasional field is badly damaged. The development and spread of stem rot is closely related to climatic conditions. It is most severe when soil moisture is high for some time and air temperatures are at 70° F. or below. Frequent rains, fog, or heavy dews favor infection by the fungus. In the field the disease is most com-

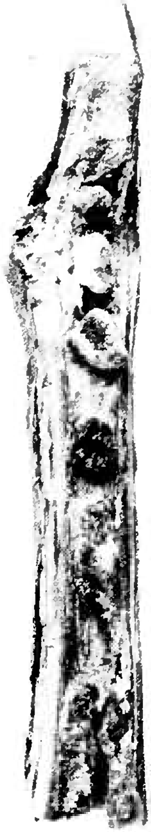

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FIGURE 10.—Stem of tomato plant killed by stem rot. The fungus has destroyed the inner tissues of the stem and the cavities contain the large sclerotia formed by the fungus. These are darker and much larger than the sclerotia of the fungus causing southern blight.

mon on tomatoes in the South Atlantic and South Central States, but occasionally it damages the crop in parts of California and the Pacific Northwest.

In the field, stem rot usually does not attack tomato plants until they reach blossoming size and develop sufficient foliage to retain moisture on and around the stem for some time after rain. The fungus mycelium may attack the stem at the soil line and cause a decay of the soft inner tissues that result in a slow wilting and eventual death of the plant.

Airborne spores of the fungus may infect leaves, stems, and fruits above the ground. As the disease progresses, a white growth covers the surface of the infected tissues. In a late stage of the disease, the stems of plants, when broken open, commonly show cavities filled with grayish-white fungus growth in which are embedded the black, hard sclerotia characteristic of this fungus. These sclerotia are larger (one-fourth inch in length) and more irregular in shape than those of the southern blight fungus and are not generally found on the surface of the stem (fig. 10). Infected fruits commonly develop a watery, soft rot.

The sclerotia retain their vitality for some time and serve to maintain the fungus in the soil from season to season. When the soil is cool and moist the sclerotia produce threads of mycelium that infect the stems near the ground. They also may produce small, cup-shaped bodies (apothecia) in which many spores are formed. These spores are ejected into the air and cause infection of the aboveground parts of the plant. In the greenhouse, infection often occurs through pruning wounds on the stems of large plants.

RECOMMENDATIONS FOR CONTROL

Plant tomatoes in well-drained fields. Do not plant tomatoes in the same field immediately after diseased crops of beans, cabbage, celery, lettuce, potatoes, or other susceptible crops. Crop rotation is necessary to control stem rot. Destroy all weeds nearby (p. 68).

To reduce the sclerotia in the soil, plant a highly resistant crop such as corn for one or two seasons. In southern Florida flooding the soil for 4 to 6 weeks during the summer will destroy nearly all the sclerotia. In the greenhouse, sterilize the soil with steam to prevent serious losses.

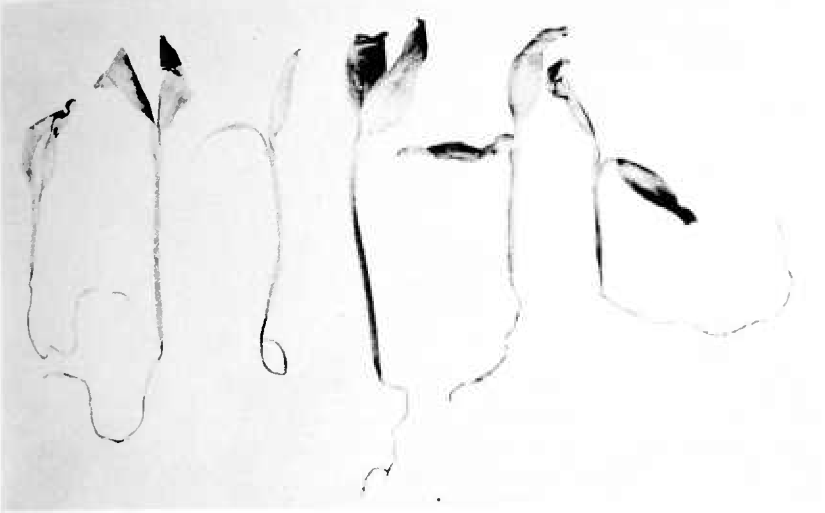

FIGURE 11.—Tomato seedlings affected with damping-off. The stems are shriveled at the ground line and the roots are killed.

Damping-Off

Tomato seedlings are particularly susceptible to damping-off. Much of this is caused by fungi of the genus *Pythium*, but some damage also occurs from infection by *Rhizoctonia solani* Kuehn or other fungi. The organisms commonly causing damping-off are in most agricultural soils, and the disease is not confined to any region. It occurs in field, greenhouse, and hotbed plantings.

The injury from damping-off fungi is of two types. One of these, known as preemergence damping-off, consists of a decay of the germinating seed or a killing of the seedling before it can push through the soil. This injury is a common cause of poor stands, which are often attributed to inferior quality of the seed.

The other type of the disease, known as postemergence damping-off, is the one ordinarily associated with the words "damping-off." It occurs after the seedlings have emerged from the soil but while they are still small and tender. The roots may be killed, and affected plants show water soaking and shriveling of the stems at the ground line (fig. 11) and soon fall over and die. Damping-off usually occurs in small patches at various places in the seedbeds; these spots often increase in size from day to day until the seedlings reach such a size that they are no longer susceptible to attack.

Seedlings are extremely susceptible to damping-off for 2 weeks after they emerge; as the stem hardens and increases in size, the injury no longer occurs. Some seedlings are not killed at once, but the roots are severely damaged and the stem is girdled at the ground line. Such plants remain stunted and often do not survive transplanting.

RECOMMENDATIONS FOR CONTROL

Excessive soil moisture is commonly associated with preemergence and postemergence damping-off, but losses may occur where soils are only moderately moist. Rapidly growing succulent seedlings are especially susceptible. Do not grow seedlings in poorly drained seedbeds or fields. (See also p. 70).

When damping-off fungi are known to be in the soil, rid the soil of them by steam (p. 73) or chemical (p. 73) treatments. For treating small quantities of soil for use in flats, use the concentrated formaldehyde solution (p. 75). Such treatments do not, however, prevent the recontamination of the soil with damping-off fungi, and the disease may later reappear.

Soil sterilization, however, is expensive and time consuming, and usually you can control damping-off without using it by treating the seed with one of the protective fungicides (p. 71). They may vary in effectiveness under certain unusual soil or environmental conditions, but all have given good results.

Protective fungicides are not necessarily effective against postemergence damping-off. You can sometimes check this by spraying the soil with Semesan, thiram, captan, or fixed copper fungicides prepared as described in the sections on "Seed Treatment" (p. 70) and "Spraying and Dusting" (p. 76).

Late Blight

Late blight of tomatoes is caused by *Phytophthora infestans* (Mont.) DBy., a fungus which also causes late blight of potatoes. The leaf symptoms are similar on the two hosts. The disease causes severe defoliation of tomatoes and a destructive rot of the fruit. In the higher lands of West Virginia and Pennsylvania, some areas in New England, and certain areas on the Pacific coast, the disease has occurred rather regularly on tomato for many years. Elsewhere, late blight was comparatively unknown until 1946, when an epidemic of the disease destroyed much of the crop in a large part of the tomato-growing areas of the eastern United States. Since that time the disease generally has been less severe, but occurs sporadically in severe form in some areas in the Central and Atlantic States. Late blight also sometimes damages greenhouse crops. It occasionally is found on eggplant, but it does not seem to occur on pepper.

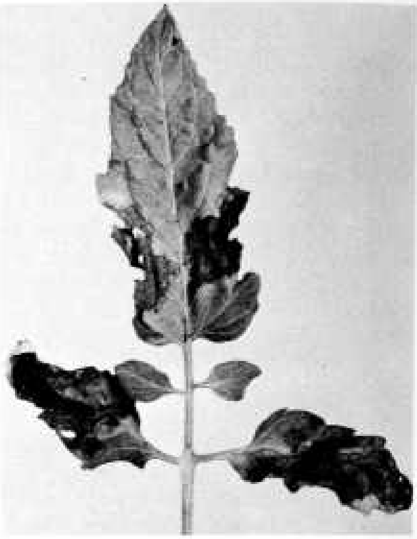

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FIGURE 12.—Tomato leaflets showing the dark patches of dead tissue characteristic of late blight.

At first, irregular, greenish-black, water-soaked patches appear on the older leaves (fig. 12). These spots enlarge rapidly, and, in moist weather, sometimes a white, downy growth of the fungus developes on their lower surfaces. The stems also may have water-soaked, brown areas similar to those on the leaves. In moderately warm, wet weather the infection spreads so rapidly at times that almost all the foliage is affected, and the plants look as though they had been damaged by frost.

Infection of fruit occurs at any stage of growth. It is most common on the upper half of the fruit, but it may occur elsewhere on the surface. The first symptom is a

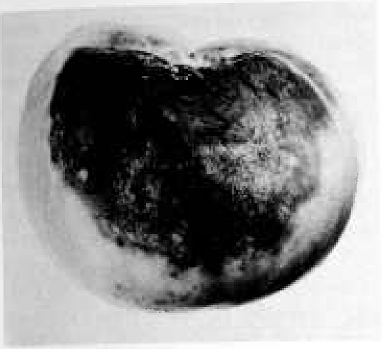

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FIGURE 13.—Green tomato showing the discoloration and wrinkled appearance of the surface, resulting from infection by the fungus causing late blight.

grayish-green, water-soaked spot; this enlarges until it may cover half the surface. The spot becomes brown and has a firm, corrugated surface (fig. 13) that occasionally shows narrow, zonate markings that may be confused with the broader markings of buckeye rot (p. 34). The margin of the spot may be somewhat indefinite, but usually it is slightly sunken where decayed and healthy tissues join. Under moist conditions a white, downy growth of the fungus appears on the fruit.

In moist weather the fungus produces abundant spores on the undersurfaces of the leaves and occasionally on the fruit. These may be splashed to other plants by rain or carried some distance by the wind. Aerial spread of the spores may be responsible for the gradual spread of the fungus over considerable areas. In moist weather the spores germinate readily at temperatures of 40° to 70° F., but they are soon killed at 75° to 80° in dry weather. After infection, the fungus invades the plant rapidly at temperatures of 70° to 80°. Cool nights and only moderately warm days with abundant moisture favor development of late blight. Mean temperatures much above 70° are likely to check it, especially in dry weather. Fruits show decay within a week after infection. Many that seem sound when taken from fields where late blight occurs may decay by the time they reach market.

Phytophthora infestans does not seem to survive on dead plant tissue in the soil, but it does persist in infected potato tubers. It may appear in plants from diseased tubers used as seed, on volunteer plants from tubers left in the soil, or plants from tubers in potato refuse piles. There is a report of the fungus being carried on tomato seed, but this has not been confirmed. The disease often appears on the winter crop of potatoes in the South. The fungus may be transmitted from the potato to tomato plant beds, and transplants shipped from such beds may carry the organism to northern areas. In the northern areas tomatoes may be infected from potato fields. The disease sometimes occurs during the winter and spring on tomatoes in the greenhouse, and these are a potential source of infection to seedlings grown nearby and to plants in the field.

There are races, or strains, of the fungus that vary in the severity of their effect on tomatoes and potatoes, respectively. The common tomato race of the fungus produces spores on leaves of both tomato and potato, and the same is true of the potato races. The tomato race damages potatoes about as much as the races for which potato is a preferred host. The potato races, however, affect potatoes more severely than tomatoes. The tomato race is carried over in potato tubers. There is evidence that several passages of a potato race through tomato plants may alter its racial character. Potato races can frequently be isolated from tomato and vice versa, but any race is most commonly found on the host species for which it is named.

RECOMMENDATIONS FOR CONTROL

Do not follow potatoes with tomatoes in the same field (p. 67). Also avoid planting tomatoes near potato plantings. Since the disease sometimes occurs on transplants from the South, always use plants from fields certified as free from the disease. Do not use seedlings grown in greenhouses where late blight is present on mature plants.

Spray with maneb (p. 80), zineb (p. 81), nabam (used with zinc sulfate) (p. 80), or a fixed copper compound (p. 80) to reduce losses from late blight. Bordeaux mixture (p. 78) may be used late in the season for emergency control of late blight. If zineb, nabam (used with zinc sulfate), or a copper fungicide is used in regions where anthracnose is a problem, alternate with applications of ziram (p. 81). If gray mold is a problem, combine zineb with dichlone or ferbam (p. 79). Begin spraying or dusting whenever late blight threatens to appear or is found in the field. If late blight is present in the area, continue applications until harvest. (See also timing and methods of application of fungicides, pp. 77 and 78).

The U.S. Department of Agriculture in cooperation with the State agricultural stations maintains a late blight forecasting and warning service that enables growers to determine the time when spraying should begin.

The variety New Hampshire Surecrop has a high resistance to the common tomato races of the late blight fungus and moderate resistance to *Alternaria solani*, which causes early blight (p. 18). It is an early, determinate variety with a rather concentrated set of fruit somewhat below the average size of those of many market varieties.

Early Blight

Early blight, caused by *Alternaria solani* (Ell. and G. Martin) Sor., occurs to some extent in most tomato-growing regions and is one of the most common and serious diseases of this crop in the New England, Atlantic, and Central States. It is of comparatively minor importance in the Pacific Coast States, but occasionally there are local losses where conditions favor its development. The fungus causes a stem canker or collar rot that greatly damages young seedlings and transplants in the field; it causes spotting of the leaves that may partially defoliate the plants and greatly reduce the size and quality of the crop. This fungus also attacks the fruits and may cause them to drop before they mature or to develop dark, decayed spots as they ripen.

In the field, small, irregular, brown, dead spots usually first appear on the older leaves. The spots enlarge until they are one-fourth to one-half inch in diameter; as they enlarge, they commonly show ridged, concentric rings in a target pattern (fig. 14, *A*). These spots usually are surrounded by a diffuse yellow zone; when spotting is abundant, the entire leaf often is yellowed. Some spotting of the older leaves may appear early in the season, but the greatest injury usually occurs as the fruit begins to mature. If high temperatures and humidity occur at this time, much of the foliage frequently is killed before the end of the season. This both weakens the plants and exposes the fruit to injury from sunscald.

On the stem, early blight causes small, dark, slightly sunken areas that enlarge to form circular or elongated spots with light centers, which occasionally show concentric markings like those on the leaves (fig. 14, *B*). Large spots often appear on the stems of seedlings at the ground line, causing the partial girdling known as collar rot (fig. 14, *C*). When set in the field, such plants often die. If they do not die,

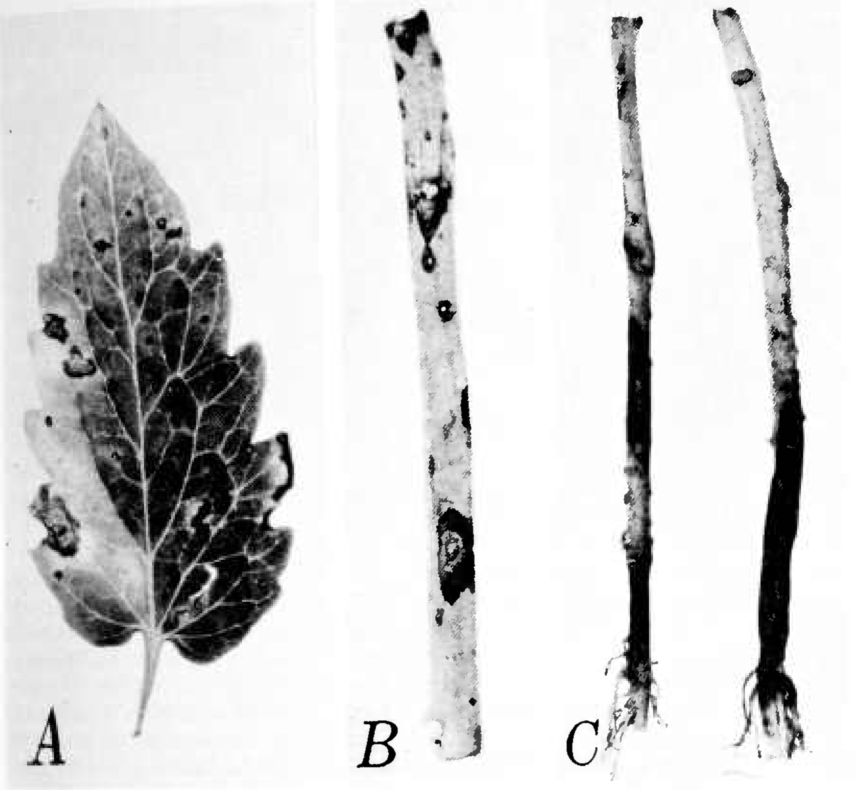

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FIGURE 14.—Leaflet and stems of tomato showing symptoms of early blight: *A*, Leaflet showing spots with characteristic targetlike markings and yellowing; *B*, cankers on stem of an older plant; *C*, collar rot injury on seedling stems.

the stem is so weakened that it breaks over early in the season; then the plant has to depend on a reduced root system that develops where the part of the stem above the canker is in contact with the soil. Such plants remain small and produce few fruits. On the older plants the stem cankers that occur later in the season are most numerous on the lower part of the shoots. Usually the center of the canker is light brown and the margin dark brown. The cankers may be so numerous as to almost cover the stem.

Early blight also causes spotting of the fruit stems and may cause some blossom drop and loss of young fruits. On older fruits it causes dark, leathery, sunken spots at the points of attachment to the stems. These spots reach a considerable size and may show concentric markings like those on the leaf (fig. 15). The dark, dry decay extends to some depth into the flesh of the fruit. Infected fruits frequently drop; if they reach maturity, they are not fit for market or canning.

The fungus that causes early blight of tomatoes also causes early blight of potatoes. It attacks eggplant and also horsenettle, nightshade, and certain other wild plants related to the tomato. The fungus may occur on or in the seed; but internal infection is rare in seed produced commercially, since seed is commonly obtained from tomatoes used for manufactured products

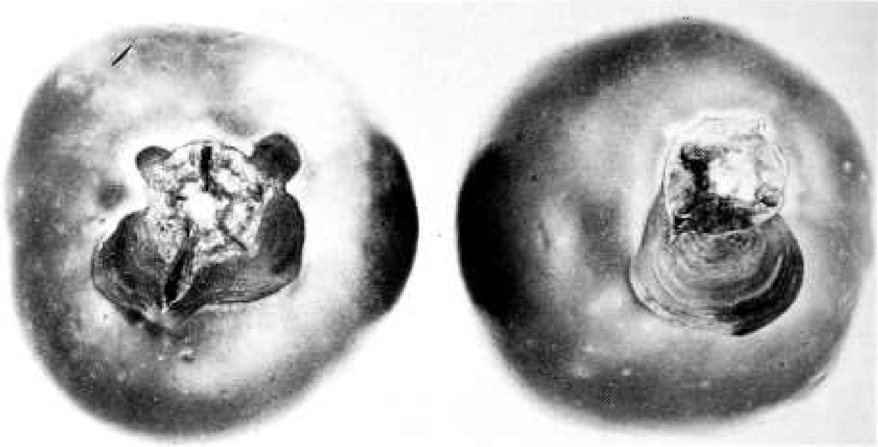
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FIGURE 15.—Tomatoes showing symptoms of early blight. Infection usually takes place near the stem scar, and the spots show concentric markings.

and badly infected fruits are discarded in the manufacturing process. The organism can live on decayed plant tissue in the soil and is widely distributed in regions where climatic conditions favor the development of early blight in the field. Primary seedling infection probably is most often due to the fungus in the soil and occurs most abundantly during periods of rain or extremely humid weather when the air temperatures are above 75° F. Crowding of plants in the seedbed favors the rapid spread of the disease, and poorly nourished plants seem most susceptible. In the field the spores produced in the spots on the leaves and stems are spread by wind, rain, or human beings to adjacent plants, and, when climatic conditions favor infection, the disease soon becomes general. Plants carrying a heavy load of fruit appear to be more susceptible than those in an earlier stage of growth.

RECOMMENDATIONS FOR CONTROL

Prevention of seedling infection is very important in controlling early blight. Treat the seed with a surface disinfectant (p. 70). If permanent beds are used, replace the soil or disinfect it by treatment with steam (p. 73) or a chemical disinfectant (p. 74). Where plants are grown in hotbeds or coldframes, provide ample ventilation (p. 69). It is best to abandon plant beds containing numerous plants with collar rot, stem cankers, or leaf spotting, since further stem infection is likely to develop after transplanting to the field. If plants are purchased, do not buy from shipments in which many of the plants show infection. Do not hold plants in the beds for long periods after they reach transplanting size; crowding increases the danger of infection.

In both the seedbed and the field, spray or dust with preparations of maneb (p. 80), zineb (p. 81), or nabam (used with zinc sulfate) (p. 80) to reduce the damage from early blight. Fixed copper compounds (p. 80) are fairly effective, but these do not give so good control of anthracnose (p. 33) and gray leaf spot (p. 32) as the compounds first mentioned. (For the timing and number of applications of fungicides, see p. 77.)

Leaves and fruit of the tomato varieties now in use do not show pronounced resistance to the early blight fungus. However, the varieties Manalucie, Southland, and New Hampshire Surecrop are moderately resistant to infection and on these varieties the disease is more easily controlled by fungicides.

Nailhead Spot

Prior to 1926 the disease of tomato fruits known as nailhead spot, caused by *Alternaria tomato* (Cke.) Brinkman, was one of the most serious diseases affecting the tomato crop in Florida. It also caused some losses in other South Atlantic States and in the South Central States. In 1926, the introduction of the Marglobe variety, whose fruits are resistant to infection, greatly reduced the losses from this disease. Since then the general use of nailhead-resistant varieties has made it of minor importance. Potato, eggplant, and horsenettle have been artificially infected with the fungus, but natural infection has only been found on tomato.

In both the seedbed and the field, the symptoms of nailhead spot on the leaves and stems are almost identical with those of early blight (p. 18), which is caused by a closely related fungus. On the fruits, however, the nailhead spotting is quite unlike that caused by early blight. Fruits may be infected by the nailhead spot organism at any stage of their growth and on any part. Minute tan spots first appear; these enlarge until they are one-sixteenth to three-eighths inch in diameter. The centers of the spots first are slightly sunken, and the margins are darker. As the spots become older, the centers are more definitely sunken and become grayish brown, with the surfaces roughened by the drying and tearing-back of the epidermis (fig. 16 and cover). When very numerous, the spots coalesce and often cause irregularities in the shape of fruits infected when small. In ripening fruits the tissues immediately around the spots often remain green. The fungus ordinarily does not penetrate deeply into the fruit,

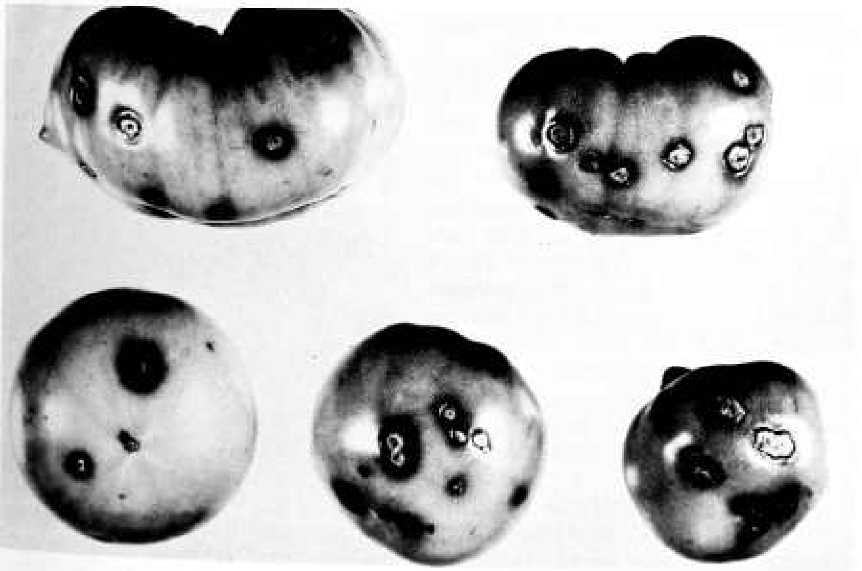
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FIGURE 16.—Tomatoes affected with nailhead spot. The spots have grayish-brown centers and darker margins; their surfaces have a roughened, torn appearance.

but secondary infections with other organisms sometimes cause serious decay. Fruits infected but showing no symptoms when packed may develop spots in transit and storage.

The nailhead spot fungus is very similar to that causing early blight, and their life histories are almost the same. Warm, rainy weather is most conducive to infection and rapid development of the disease on the foliage and fruits. Spores are produced on the surface of the spots on the fruits, leaves, and stems. These spores are spread by wind and splashing rains. Seedling infection often can be traced to the presence of the organism in seedbed soils.

RECOMMENDATIONS FOR CONTROL

Follow recommendations for seedbed sanitation, seed treatments, and spraying as given for early blight (p. 20). However, the most effective means of preventing losses from fruit infection is to grow varieties whose fruit are resistant to the nailhead fungus. Since the disease is now rare in the South Atlantic States, it is probable that most of the varieties in general use have such resistance.

Gray Mold

Gray mold, caused by the fungus *Botrytis cinerea* Fr., has become one of the most serious diseases of tomato foliage and fruit in southern Florida. The same fungus also causes a disease of the fruit known as ghost spot (p. 23). For a long time the fungus has caused a fruit rot and stem decay of greenhouse tomatoes and of fruit in transit, but since about 1955 it has caused serious damage in the field. Plants become most susceptible as they approach maturity, and large plants with heavy foliage seem to be most seriously damaged.

The fungus first becomes established on dead leaves or stems at the base of the plant. A heavy, gray growth of the fungus covers these, and numerous spores (conidia) soon appear on this. Air currents easily detach these spores and spread them to healthy plants, which become diseased when temperature and humidity favor infection.

Actively growing, infected leaves show typical light-tan or gray spots. The infected areas become covered by a growth of the fungus, and the leaf collapses and withers. As this occurs, the fungus frequently progresses into the stem and produces distinctive elliptical cankers. These extend some distance up the stem and are tan with concentric markings. Often the surface is overgrown by fungi that only affect dead tissues, and it then becomes black rather than tan.

On the fruits, water soaking and softening of the tissues at the point of infection are first noted. These spots are irregular in shape and may be an inch in diameter. Usually they are grayish or yellowish green with lighter margins. A darker gray growth of the fungus later develops on the surface of the fruit (fig. 17). Finally, the fruit is often destroyed by watery soft rot.

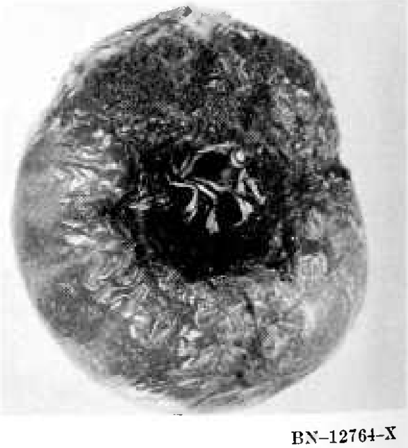

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FIGURE 17.—Tomato showing advanced symptoms of gray mold. The fruit is softened and wrinkled, and the fungus has overgrown the surface at the left of the fruit stem.

The fungus can enter the leaf through any injury. Insect wounds and spots caused by other fungus parasites are common points of entry. Fruits may be infected through the stem scar, growth cracks, abrasions from blowing sand, or other breaks in the epidermis. The disease seems to be most common and severe during periods of cool, wet weather.

RECOMMENDATIONS FOR CONTROL

In Florida, gray mold has been more severe on plants sprayed with maneb (p. 80), zineb (p. 81), or nabam (used with zinc sulfate) (p. 80) than on untreated plants. The reasons for this are not fully understood. A program for control of other prevalent leaf diseases must include a fungicide effective against gray mold.

Several fungicides control moderate infections with gray mold. But for severe infections dichlone and ferbam are the most effective. One of these combined with zineb controls this and some other major diseases (p. 79).

In the greenhouse, *Botrytis cinerea* often causes a stem rot of tomatoes in the winter. The stems are attacked at the soil level when low temperature and ample moisture favor infection by the fungus. To check this stem rot, cut away the infected part of the stem with a sharp knife and paint the cut surface with a strong bordeaux mixture. This treatment is laborious, but it gives good control of stem rot. A 10–10–100 bordeaux mixture (p. 78) applied as a spray to the lower part of the stem before symptoms appear also helps to control stem rot. Drench the soil at the base of the stem with this mixture at a rate of one-half pint per plant. Do not apply this until at least 2 weeks after transplanting.

In the spring, gray mold sometimes appears on the stems, leaves, and fruit. To reduce or prevent these attacks, raise the temperature and lower the humidity in the greenhouse.

Ghost Spot

Young green tomatoes sometimes have small whitish rings on their surface. These markings, called ghost spots, are caused by the fungus *Botrytis cinerea* Fr., which also causes gray mold of tomatoes (p. 22). The disease is of some importance on spring crops in southern Florida and has been found in other Atlantic States, in the Central States, and in greenhouses.

The ghost spot markings are one-eighth to three-sixteenths of an inch in diameter (fig. 18). They usually are single whitish rings, but they may be solid whitish, circular spots. Usually there is a very small, dark-brown speck near the center of the spot. The spots do not increase in size and do not extend much below the epidermis of the fruit. They do not affect the quality of the fruit. The disease is most common on green fruits 1 to 1½ inches in diameter; however, it may be found on larger fruit. The spotting usually is on the surfaces of fruits exposed to the sun and most frequently occurs on the shoulders of the fruit.

Until 1957, the cause of ghost spot in the United States was somewhat uncertain. However, the results of investigations of a similar fruit spotting in English greenhouses indicate that the disease is caused by penetration of the surface of the fruit by spores of the fungus *Botrytis cinerea*. This has been shown to be true of ghost spot on field-grown tomatoes in Florida.

When spores of the fungus are present on the surface of the fruit at a time of heavy dew or night rain with temperatures from 60° to 75° F., they germinate and penetrate the epidermis of the fruit. If bright sunlight occurs the next morning, the fungus is killed by the

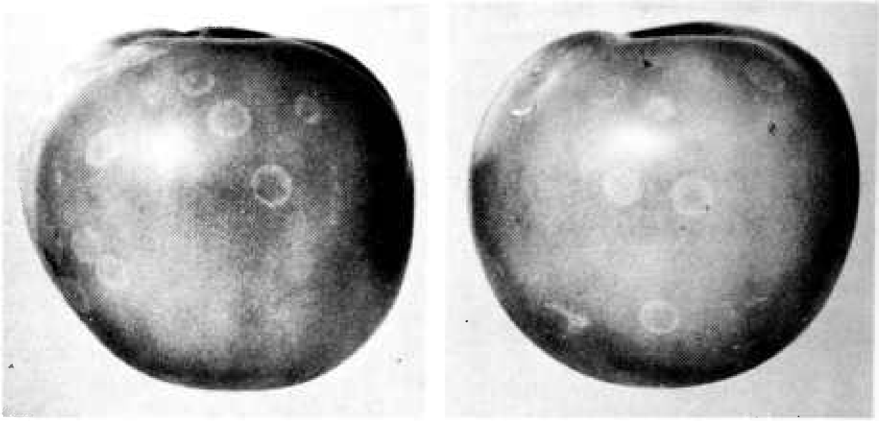

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FIGURE 18.—Tomatoes affected with ghost spot. The markings are small, whitish, rings on the surface of the fruits.

high temperature and the ghost spot markings appear. The dark speck at the center of the spot marks the point of entry of the fungus and the minute area in which it kills the cells of the fruit before its activity is stopped. The spots almost always appear on the shoulders and upper halves of immature fruits and usually on those that are exposed to the sun; this indicates that sunlight is a factor in ghost spot formation. In Florida, the disease is serious only in the spring when the above-described weather conditions are common and in fields where gray mold has occurred previously.

RECOMMENDATIONS FOR CONTROL

In regions where the disease is of importance, spray with dichlone or ferbam (p. 79), as recommended for gray mold.

Phoma Rot

Phoma rot of tomatoes, caused by *Phoma destructiva* Plowr., is responsible for much loss of fruit shipped from the South Central and South Atlantic States during fall, winter, and early spring. Minor losses have been reported from the Middle Atlantic and North Central States.

On the leaves, small, often numerous, irregular, dark spots are first noted. These soon become one-fourth to one-half inch in size and show zonate markings (fig. 19).

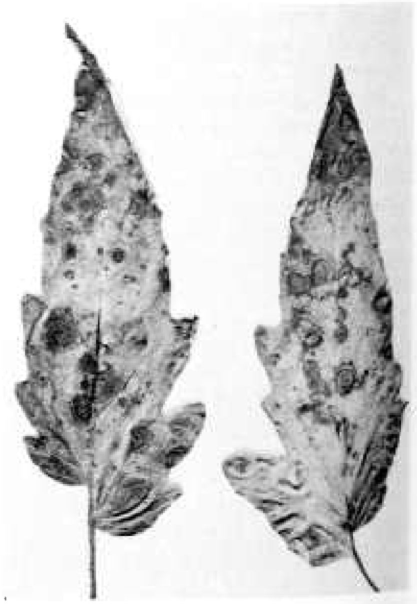

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FIGURE 19.—Tomato leaflets spotted by the fungus causing phoma rot. The concentric markings resemble those of early blight.

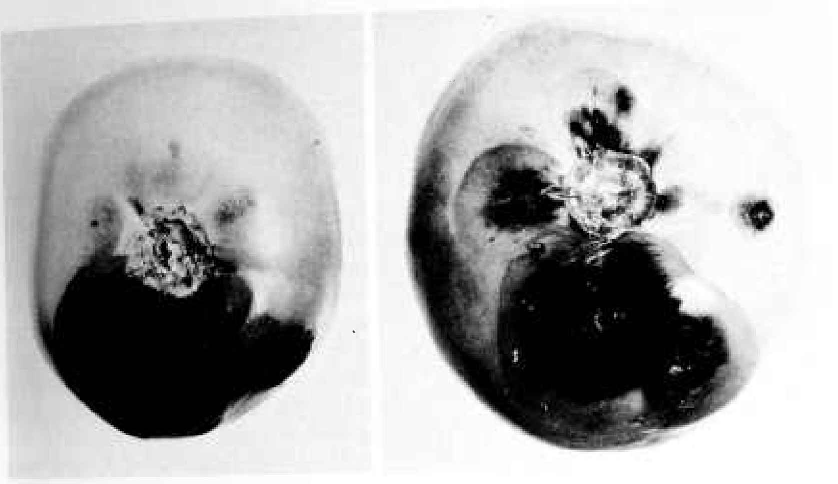
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FIGURE 20.—Ripe tomatoes showing an advanced stage of phoma rot. The centers of the spots are dark and leathery; the margins are lighter.

which may be mistaken for those caused by early blight or nailhead spot. Severely infected leaves turn yellow and wither. The stems show dark, elongated spots with faint, concentric markings. Seedling tomatoes may be severely injured by leaf and stem infections.

The greatest losses from spotting of the fruit occur during transit and in ripening rooms, but fruits also are damaged in the field. The field symptoms commonly consist of small (⅛ inch), slightly depressed spots near the stem scar that become brown and develop tiny pustules (pycnidia) in which the fungus spores are produced. On green fruits ripening after shipment the spots develop more rapidly and appear first as circular, depressed, water-soaked areas that may become ½ to 1½ inches in diameter. These spots become black and leathery and are dotted with the minute pustules (fig. 20). Such spots are most common near the stem scar; however, they may also develop at other points on the surface.

The fungus causing phoma rot can live for a time on decaying plant refuse in the soil, and much of the primary infection comes from this source. Seedling infection is common, and the disease is often carried to the field on infected plants. In the field, masses of spores are exuded from the pustules in the spots on the leaves during wet weather and are washed onto the surface of the fruit by rain or are spread by those working among the plants. Since fruits are infected only through breaks in the surface, infection is more common during shipment and ripening, because of slight injuries previously received in picking and packing. When the disease is prevalent in the field, the fungus spores are often widely distributed over the fruit during the washing and packing processes; and the high humidity that usually prevails during shipment and ripening favors infection. This infection occurs most frequently through stem scars, growth cracks, and other injuries about the stem end of the fruit. Spotting, however, may occur at other points and frequently follows the injuries caused by nailhead spot.

RECOMMENDATIONS FOR CONTROL

In sections where phoma rot occurs, locate seedbeds on clean soil and at a distance from land that has grown tomatoes during the previous season. If old seedbeds must be used, disinfect the soil by treatment with steam (p. 73) or a chemical disinfectant (p. 74). Disinfect seed with a surface disinfectant (p. 70). Where phoma is serious in the seedbed, begin spraying when the seedlings are small. To reduce the spread of the phoma rot fungus, spray or dust with maneb (p. 80), zineb (p. 81), or nabam (used with zinc sulfate) (p. 80). Do not harvest fruit when wet as this may cause the infection of healthy fruit.

Bacterial Spot

Bacterial spot, caused by *Xanthomonas vesicatoria* (Doidge) Dowson, is most noticeable in its effect on the fruit. However, it may also cause considerable injury to the foliage of seedlings and plants in the field. The disease has been reported from most tomato-producing regions and frequently causes considerable loss in the Middle and South Atlantic and Central States. It is most common in seasons with frequent rainy periods. Peppers also are often seriously damaged.

The disease is very common and destructive on seedlings and spreads rapidly in seedbeds. Leaflets show small (1/8 inch), irregular, dark spots of greasy appearance, the centers of which dry out and frequently tear. Stems of seedlings also are spotted. On older plants the leaflet infection is mostly on older leaves and there may be serious defoliation. The symptoms on the leaves may be confused with those of gray leaf spot or small spots caused by early blight. At times infection of the flower parts causes considerable blossom drop.

The most striking symptom occurs on the green fruits. Small, water-soaked spots first appear. These become slightly raised and enlarge until they are one-eighth to one-fourth inch in diameter. At first the spots have greenish-white halos and may be confused with the bird's-eye spotting characteristic of bacterial canker (p. 8). However, the halo of the bacterial spot is not so white as that of the bacterial canker spot. Furthermore, the entire spot, including the halo, is definitely raised above the surface of the fruit while the bird's-eye spot caused by the canker bacteria remains comparatively flat and does not change its appearance. The halos of bacterial spot lesions soon disappear, and the centers of the spots become irregular, light brown, and slightly sunken, with a rough, scabby surface (fig. 21). They do not extend very deep into the fruit. Ripe fruits are not infected.

The surface of the seed becomes contaminated with the bacteria during extraction from the fruit, and the organism can live for some time on the seed surface. Much of the primary infection can be traced to the seed, but there is some evidence that the organism can overwinter in the soil. Moist weather favors infection, and there often is a widespread dissemination of the organism in the field after driving rains that splash the bacteria from plant to plant. Leaf infection occurs through natural openings (stomata). Fruits have no stomata and are infected through injury from wind-blown sand, insect punctures, or other slight wounds in the surface. Fruits commonly are severely spotted on the windward side after a blowing rain.

RECOMMENDATIONS FOR CONTROL

Bacterial spot is hard to control after it appears in the field; therefore, make every effort to prevent infection of the seedlings. If trans-

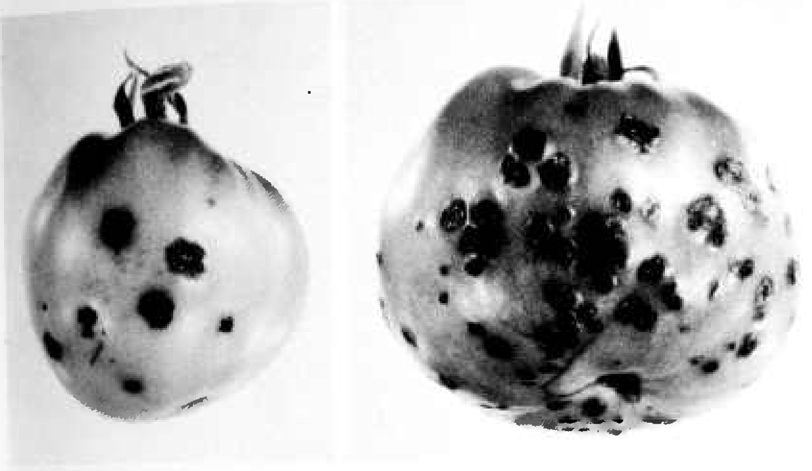

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FIGURE 21.—Tomatoes showing a late stage of bacterial spot. The spots are raised, but the centers are slightly sunken and have a rough, scabby appearance.

plants are purchased from the South, procure them from fields certified as free from disease.

Since the bacteria can be present on the seed, treat it with bichloride of mercury (p. 71) or Ceresan M (p. 72).

If possible, do not locate seedbeds on soil where bacterial spot occurred in the previous year. If permanent beds are used, disinfect the soil with chloropicrin (p. 74) or methyl bromide (p. 75).

Organic fungicides such as maneb, zineb, or captan do not control bacterial spot. Fixed copper fungicides (p. 80) are quite effective in controlling mild outbreaks of bacterial spot. A preparation of a fixed copper combined with streptomycin (Agri-mycin 500) gives good control of bacterial spot in seedbeds (p. 81).

In rainy weather, spray seedbeds every 5 or 6 days after the first leaves appear. After plants are in the field, spray with a fixed copper compound at 7-day intervals if the disease is known to be prevalent and the weather is rainy. (See also timing and methods of application of fungicides, pp. 77 and 78.)

Bacterial Speck

Bacterial speck, caused by *Pseudomonas punctulans* (M. K. Bryan) Dowson, is occasionally found in the Atlantic and Central States, but it causes little serious loss. As far as known, it affects only the tomato.

It is most noticeable on the fruit, where it causes numerous small, dark-brown, slightly raised spots that are less than one-sixteenth inch in diameter. The spots have definite margins and, like those of bacterial spot and bacterial canker, do not extend deep into the fruit (fig. 22). As both bacterial speck and bacterial spot may occur on the same fruit, the speck injury is frequently mistaken for small lesions of bacterial spot. Diseased leaves develop tiny dark spots about the size of those on the fruit. They extend through the leaf and, if numerous, cause yellowing of the surrounding tissue.

Only young fruits are susceptible. Wounds are not necessary to infection. Infection occurs most abundantly after beating rains that splash the bacteria to all parts of

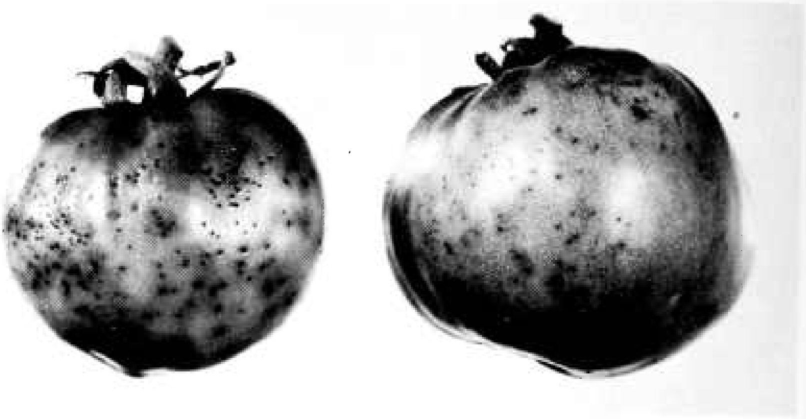

FIGURE 22.—Tomatoes showing bacterial speck. The spots are numerous and much smaller than those of bacterial spot.

the plant. The organism probably is carried on the surface of the seed.

RECOMMENDATIONS FOR CONTROL

Use the same control measures recommended for bacterial spot (p. 26).

Septoria Leaf Spot

Septoria leaf spot, or septoria blight, caused by *Septoria lycopersici* Speg., is one of the most destructive of the tomato leaf diseases. It often causes severe losses in the Middle Atlantic and Central States. It occurs rather frequently as far south as Arkansas, Tennessee, and South Carolina, but it is of minor importance in the Deep South and in the Mountain and Pacific Coast States. In seasons when temperatures are moderate and rainfall is abundant, the disease often destroys so much of the foliage that the plants fail to mature their fruits properly and there is considerable injury from sunscald.

The disease may occur on plants of any age, but in the field it usually becomes most evident after the plants have begun to set their fruit. The first infection ordinarily is found on the older leaves near the ground. Water-soaked spots, which often are scattered thickly over the leaf, are first noted. These spots soon become roughly circular and have gray centers surrounded by darker margins. Later the centers show tiny dark specks in which the spores of the fungus are produced (fig. 23). The spots are smaller and more numerous than those of early blight; usually they are one-sixteenth to one-eighth inch in diameter. If they are numerous, the leaflet eventually dies and drops from the plant. When conditions favor infection, there is a progressive loss of foliage until only a few leaves are left at the top of the stem, and the fruits are exposed to sunscald. The fruits are rarely affected, but there may be spotting of the stem and blossoms.

The fungus that causes septoria leaf spot also attacks wild relatives of the tomato, such as jimsonweed, horsenettle, groundcherry, and nightshade. It overwinters on the remains of tomato plants or weed hosts or on other decaying vegetation. The first infection results from the spread of the spores produced on such material to the leaves of the tomato. After infection occurs numerous spores are produced in the dark specks formed in the leaf spots. During wet weather these spores are exuded onto the

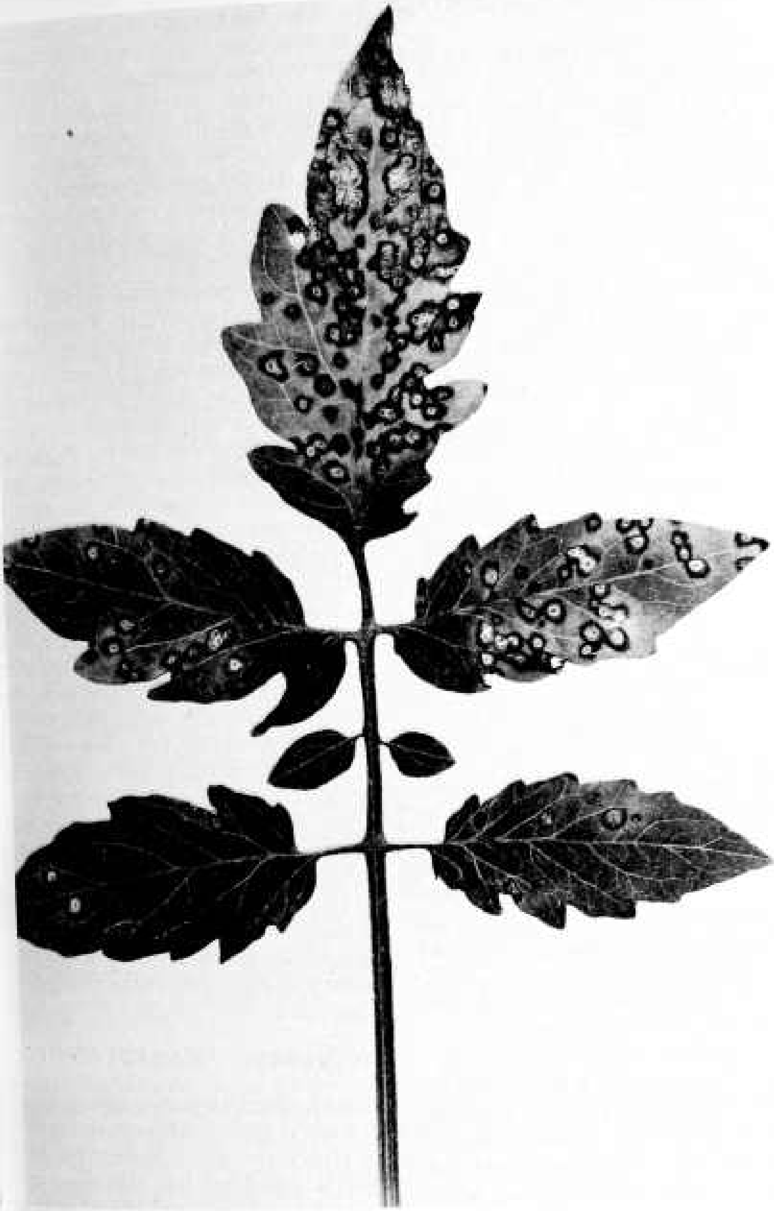

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FIGURE 23.—Tomato leaf affected with septoria leaf spot. The spots have light centers and darker margins. From the dark specks in the centers of the spots masses of fungus spores are exuded in wet weather.

leaf and are splashed onto other leaves by rain or spread by brushing against the moist foliage. The fungus is most active when temperatures range from 60° to 80° F. and rainfall is abundant. During hot, dry seasons it causes little damage.

RECOMMENDATIONS FOR CONTROL

Plow under all crop refuse; this leaf spot fungus will not live over on the remains of plants buried deeply in the soil (see p. 68). Since weeds harbor the fungus, clean cultivate and control weeds. Use long rotations, particularly with legumes or cereals, to help free the fields of the fungus.

The disease is more difficult to control with fungicides than is early blight. The fixed copper compounds (p. 80), maneb (p. 80), and zineb (p. 81) seem to be the most consistently effective in controlling septoria leaf spot. Apply the fungicides before the disease appears in the field. The number of applications will depend on weather conditions (p. 77); usually about the same number are needed as for early blight. (See also timing and methods of application of fungicides, pp. 77 and 78.)

Leaf Mold

Leaf mold, caused by *Cladosporium fulvum* Cke., is one of the most common and destructive diseases of greenhouse tomatoes. In some of the South Central and South Atlantic States the disease may be of considerable importance in the field in wet seasons, and occasionally it is serious in the East North Central and Middle Atlantic States.

First, diffuse whitish spots appear on the upper surfaces of the older leaves; these rapidly enlarge and become yellow. Under humid conditions the lower surfaces of these patches become covered with a velvety, olive-brown coating of the causal fungus (fig. 24). When conditions favor the development of the disease in the greenhouse, much of the foliage eventually is killed and the crop is greatly reduced. The fruit stems and blossoms occasionally may also be infected; fruit infection is rare.

The fungus spores are produced in great numbers on the undersurfaces of the leaves and are spread by air currents, watering, and contact with the plants. The spores are resistant to drying and may survive in the greenhouse for several months after the plants have been removed. Occasionally the spores may be carried on the seed.

Spore germination and leaf infection occur only when the relative humidity is high (90 to 100 percent) at the leaf surface. Therefore, the fungus is most destructive when the humidity is high and temperatures range from 65° to 80° F. High relative humidity may occur at the leaf surface and immediately around the leaves when the relative humidity is considerably lower in the open parts of the greenhouse. The reasons are that the leaf itself gives off some moisture and there often is a condensation of moisture on the leaves from the air. Therefore, the disease is usually most destructive in the greenhouse from May to November, when the relative humidity is likely to be high and air temperatures are such that heating is not continuous. As the air temperatures drop after sundown, the relative humidity rises until (usually about midnight) it approaches saturation at the leaf surface; conditions are then favorable for infection.

RECOMMENDATIONS FOR CONTROL

In the field, to reduce injury from leaf mold spray with maneb (p. 80) or zineb (p. 81). Ziram (p. 81) also is effective, but this does not control late blight (p. 16). Use this in alternating applications with a fixed copper fungicide (p. 81) in regions where late blight occurs. Start applying a fungicide about the time the first fruits are set or earlier if the disease has appeared in the field. (See also timing and methods of application of fungicides, pp. 77 and 78.)

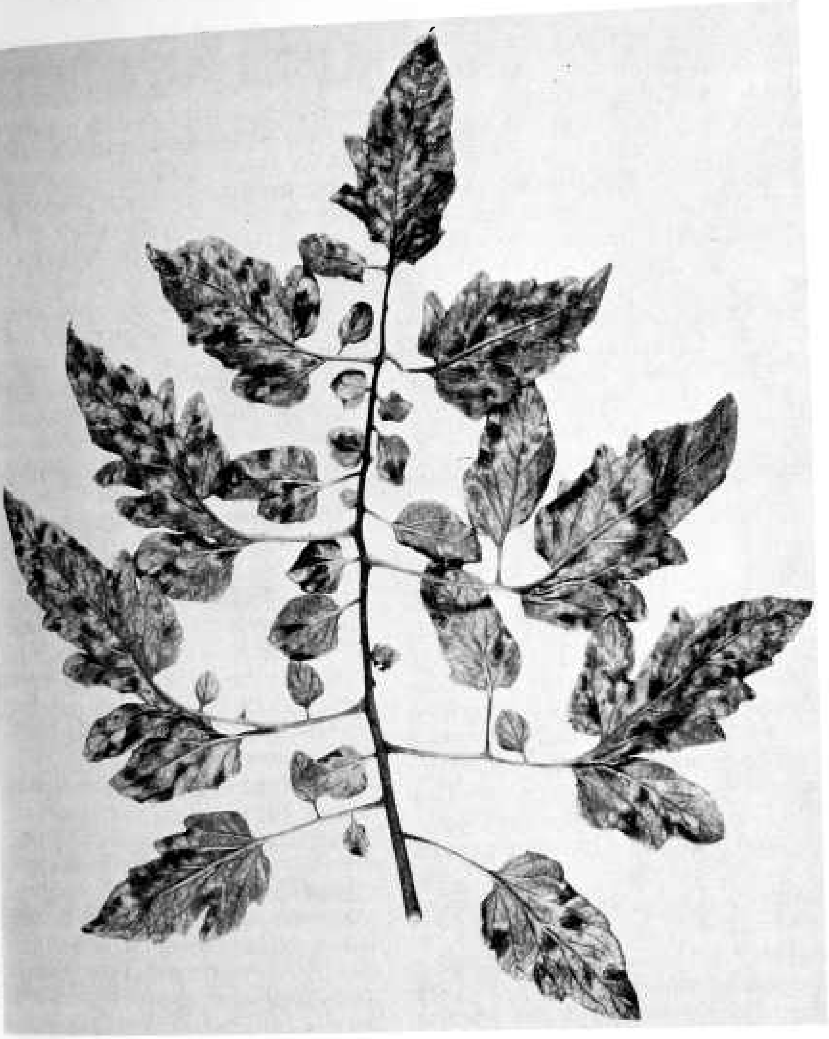

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FIGURE 24.—Underside of a tomato leaf, showing dark patches of the leaf mold fungus. These patches are covered with spores, which are readily detached and spread to healthy foliage. (Courtesy of the Ohio Agricultural Experiment Station.)

In greenhouses in the United States, fungicides have never successfully controlled this disease. The chief means of control in the large greenhouse industry in the North Central States is to keep the humidity low enough to prevent the development and spread of the fungus (p. 69). Frequently this can be done by supplying ample ventilation and good air circulation in the greenhouses.

During the warmer spring and fall months, provide maximum ventilation and supply sufficient heat to maintain temperatures of at least 60° to 65° F. To avoid some of the increase in relative humidity that comes with a lowering of the air temperature, provide heat at night when the outside temperature drops below 60°. In the Central States many growers use some heat at night until the first week in July, almost regardless of the temperature, and commence night heating again during late August or early September. The combination of heat and ventilation sets up currents of air that help to prevent moisture accumulating on the foliage. The disease usually will not be severe if the relative humidity is kept below 90 percent. Forced circulation of air by fans or blowers has been tried, but their installation is expensive and results have not been satisfactory.

In the greenhouse, the best means of control is the use of resistant varieties. Such varieties have been developed; but, with their first introduction, races of the fungus appeared to which they were susceptible. This has been true with Globelle, a large-fruited, pink variety, and with Bay State and Vetomold, which are smaller fruited, red varieties. The varieties, Improved Bay State, Waltham Mold-Proof Forcing, and Vinegreen have high resistance to all known races of the fungus. They are medium-sized, red-fruited varieties adapted to markets in the Northeastern States and in Canada. They have not been used in the greenhouses of the North Central States where larger fruited varieties are desired and pink-fruited varieties are very popular.

Gray Leaf Spot

Gray leaf spot, caused by *Stemphylium solani* Weber, is a common and destructive disease of tomatoes in the Southeastern States. It also occurs in Texas and has caused losses of varying severity in Illinois, Indiana, Ohio, and in the Middle Atlantic States. The disease, unlike early blight and nailhead spot, does not affect the fruit. The causal fungus also infects pepper eggplant, and red-currant tomato. Groundcherry and horsenettle are weed hosts. The disease is most common in warm, moist weather.

The first infection usually occurs on the older leaves; numerous small, dark-brown spots (fig. 25, *A*) that extend through to the undersurface of the leaf (fig. 25, *B*) appear. These spots generally remain small, but they may enlarge until they are one-eighth inch in diameter. As they enlarge, the spots develop a grayish-brown glazed appearance (fig. 25, *C*) and at times the centers crack and tear across. When the spots are numerous on the foliage of plants in the field, the leaves become yellow and eventually wither and drop. This yellowing is less noticeable, however, on seedling plants. When conditions are especially favorable for gray leaf spot, all the leaves except those near the tips may be killed and few fruits are produced. Spots also sometimes form on the stems, but this injury is not severe.

The fungus is carried over from season to season on the remains of diseased plants in the soil, and much of the primary infection can be traced to this source. Seedlings often are infected as soon as they emerge, and seedbeds are sometimes destroyed by the disease. Plants from seed sown directly in the field may be infected. The fungus spores are spread by air currents, and infected transplants may carry the fungus to clean fields.

RECOMMENDATIONS FOR CONTROL

Control measures for gray leaf spot are much like those for early blight (p. 20). Use the same chemicals for seedbed and coldframe soil disinfection and to disinfect the surface of the seed. Use a 3- or 4-year rotation of the tomato crop. To reduce losses, start spraying or dusting with zineb (p. 81) or maneb (p. 80) in the seedbeds and continue until harvest. Nabam used with

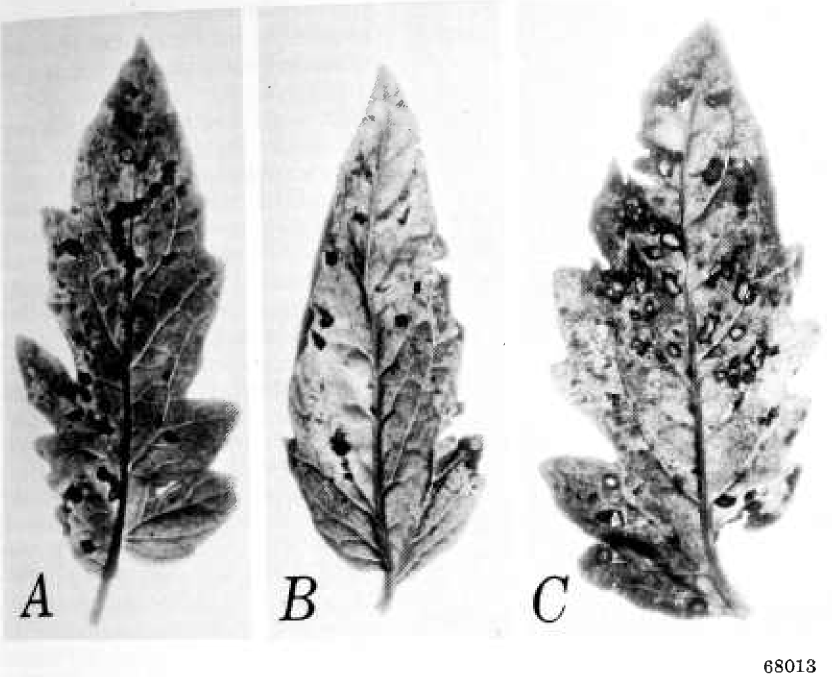

FIGURE 25.—Tomato leaflets affected with gray leaf spot: *A*, Leaflet showing numerous small spots typical of the early stage of the disease; *B*, undersurface of leaflet showing spotting; *C*, leaflet showing light-colored spots occurring in later stages of infection.

zinc sulfate has been effective in Florida. But, wherever it has been used, it appears to cause some injury to the plants and reduce yields as compared with those sprayed with maneb or zineb. Tests with the fungicide Z,4-dichloro-6-(o-chloroamilino)-S-triazine (Dyrene) (p. 81) indicate that it is effective against gray leaf spot. However, it does not give good control of late blight; therefore, consider this in regions where late blight is prevalent. If gray mold is a problem, combine zineb with dichlone or ferbam (p. 79). (See also timing and methods of application of fungicides, pp. 77 and 78.)

The varieties Manalucie and Manalee, developed for use in Florida, are highly resistant to gray leaf spot. No varieties grown for processing or fresh market in the North Central and Middle Atlantic States are markedly resistant to the disease.

Anthracnose

Anthracnose, caused by the fungus *Colletotrichum phomoides* (Sacc.) Chester, is a common and widely distributed rot of ripe tomatoes. It causes serious losses to processing crops in the Atlantic and Central States, but in regions where the crop is harvested green for shipment to distant markets it is not of great importance. In Ontario, a similar ripe rot is reported to be caused by a related fungus, *Colletotrichum atramentarium* Von Arx. (Berk. & Br.) Taub.

While spotting of the fruit is the major symptom of anthracnose, there also may be some leaf infection. Each leaf spot is a small, dark area of dead tissue often surrounded by a zone of yellow. The oldest

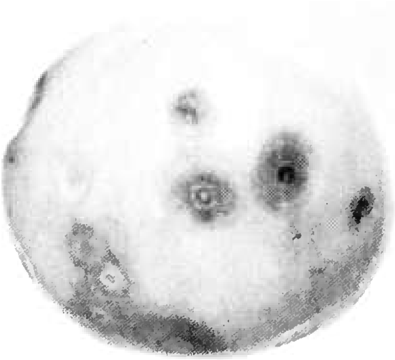

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FIGURE 26.—Tomato showing the circular, sunken spots with concentric markings in the centers characteristic of anthracnose. In wet weather the spots become covered with salmon-colored masses of the fungus spores, which are splashed by rain to other fruits.

leaves are most commonly infected.

At first, infected fruits show small, slightly sunken, water-soaked, circular spots. These spots soon become about one-half inch in diameter, darker, and more depressed and often have concentric-ring markings. The centers sometimes become tan and have numerous dark specks, which are bodies in which spores of the fungus are produced (fig. 26). In moist weather these bodies often produce masses of salmon-colored spores, which give the centers of the spots a characteristic salmon color. In warm weather the rot soon penetrates into the fruit and renders it worthless.

The fungus persists from season to season on infected plant refuse in the soil. The initial fruit infection sometimes may come from infected leaves, but most fruits probably are infected from conidia (spores) produced in the soil. The fungus can penetrate the cuticle of uninjured fruits. Fruits may be infected when green and small, but they show no evident spotting until they begin to ripen. They become increasingly susceptible as they approach maturity. Fruits on plants partially defoliated by leaf-spot diseases are especially subject to infection.

In moist weather the conidia produced on the surface of the fruit are splashed to other fruits by rain or spread by pickers. Overhead irrigation favors the spread of the disease. When conditions favor the development of the fungus, many fruits may be damaged in a short time.

RECOMMENDATIONS FOR CONTROL

Anthracnose is likely to be prevalent on poorly drained soils; therefore, avoid such soils. Since the fungus lives from season to season in the soil, use a 3- or 4-year rotation. Treat the seed with Ceresan M (p. 72). No varieties are markedly resistant.

Use fungicides for the control of anthracnose as part of the program adopted for control of early blight (p. 20), late blight (p. 18), and other leaf-spot diseases. The organic fungicide maneb (p. 80) is very effective against anthracnose, early blight, and late blight. Zineb (p. 81) and nabam (used with zinc sulfate) (p. 80) are less effective against anthracnose. Ziram is very effective against anthracnose, but it does not control late blight. Where late blight is prevalent, ziram can be used in alternating applications with other chemicals (p. 81) or in tank-mix formulations (p. 81). Use the same schedule of applications as for early blight. But, if picking continues late in the season, you may need additional applications to protect the fruit. (See also timing and methods of application of fungicides, pp. 77 and 78.)

Buckeye Rot

Buckeye rot is a fungus disease of tomato fruits. It also affects fruits of eggplant and pepper. It is most prevalent in regions subject to prolonged periods of warm, wet weather. In the field the rot is largely confined to fruits in contact with the soil; either green or ripe fruits may be infected. This rot occurs rather commonly in the South Atlantic and South Central States, where tomatoes are grown for shipment to northern markets; it causes loss of fruits in transit as well as in the field. The disease also is found in other tomato-producing regions, but ordinarily it is of only local importance there. In the Southeastern States the disease is commonly caused by *Phytophthora parasitica* Dast.,[3] but in California *P. capsici* Leonian and *P. drechsleri* Tucker appear to cause most of the damage.

The first symptom is a grayish-green or brown, water-soaked spot that usually occurs where the fruit touches the soil. In warm weather the spot enlarges rapidly and may cover half or more of the fruit. It may have no definite markings, but it usually has darker zonate bands. These markings give the disease its name "buckeye rot" (fig. 27) and are a distinguishing characteristic. However, fruits affected with late blight rot occasionally have similar markings. The surface of the spot is firm and has a smooth and not sharply defined margin. This distinguishes buckeye rot from late blight, whose spots have a roughened surface and are slightly sunken at the margin. Also buckeye rot differs from late blight in that the green fruits do not become soft for some time after infection and that it affects only the fruits.

The fungus lives in the soil and, since it requires abundant moisture for its development, is most common in poorly drained fields. It penetrates the uninjured surface of the fruit, and infection occurs either where the fruit touches the soil or where soil is splashed on the fruit by rain. When infected just before harvest, fruits in green-wrap shipments often show no evidence of the disease when packed; but they develop the rot during transit and in the ripening rooms.

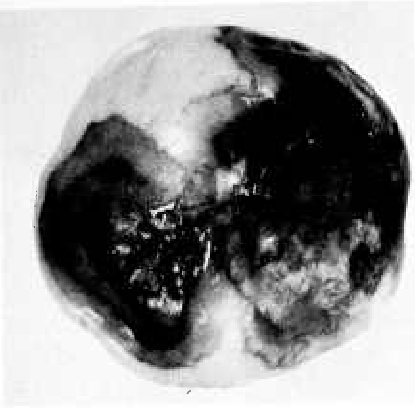

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FIGURE 27.—Tomato showing the concentric markings and discoloration associated with buckeye rot. Fruits are infected by fungus spores from the soil.

RECOMMENDATIONS FOR CONTROL

Since the fungus infests the soil, use a 3-year rotation to reduce loss. Avoid poorly drained soils. In small plantings, to keep the fruit off the soil and reduce the splashing of soil onto them by rain, mulch the plants and, if economically practicable, stake them. In irrigated plantings, set the plants on ridges to reduce fruit infection.

Spray with a fixed copper fungicide alone (p. 80) or in combination with maneb (p. 80) or with captan (p. 81).

Soil Rot

Soil rot of tomato fruits is caused by the fungus *Rhizoctonia solani*, which is likely to be in the soil wherever tomatoes are grown in the field. This fungus also may cause damping-off (p. 15) and girdling of

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[3] Synonym of *Phytophthora terrestris* Sherb.

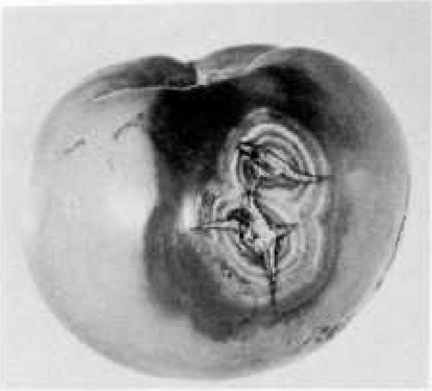
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FIGURE 28.—Tomato showing symptoms of soil rot. The surface is broken and the concentric markings of the spot are narrower and more sharply outlined than those of buckeye rot.

seedling plants. It is found on fruits both in the field and in transit.

The first symptom is a brown, slightly sunken spot about ¾ inch in diameter (fig. 28). The spot has sharply outlined, concentric zonate markings that are narrower and closer together than those of buckeye rot (p. 35). This spot gradually enlarges until it may be more than an inch in diameter, and the markings tend to become less evident. as it enlarges, the spot becomes dark brown and the center frequently breaks open. This rupturing of the surface of the spot, as well as the narrowness of the concentric markings, distinguishes the disease from buckeye rot.

The fungus causing soil rot penetrates the fruit through wounds or the unbroken epidermis. Infection is most common during periods of wet weather on moist soils where the plants cover the ground. Moderate temperatures also favor the development of the disease. Infection is not likely to occur except where fruits are in contact with the soil or where soil has been splashed on them by rain.

RECOMMENDATIONS FOR CONTROL

Since soil rot is most common on wet soils, do not plant tomatoes on low, poorly drained land. In small plantings, stake the plants; this will almost eliminate the disease. Spraying is of little value.

Minor Fruit Rots

The tomato fruit is subject to rots caused by species of *Fusarium*, *Oospora*, *Cladosporium*, *Pleospora*, *Rhizopus*, *Botrytis*, and other fungi and by various bacteria, particularly *Erwinia aroideae* (Townsend) Holland and *E. carotovora* (Jones) Holland. These rots are not of great economic importance since many of these organisms do not attack leaves or stems and usually infect the fruits only through growth cracks, insect punctures, mechanical injuries occurring in harvesting and packing, or the lesions caused by the common fruit-spotting organisms. Fruits that show these rots in the field. however, are so severely damaged as to be worthless; usually the invading organisms progress rapidly, and many of the rots are of a soft, watery type with an odor of fermentation. Green mold rot, caused by a species of *Cladosporium* other than that causing leaf mold, and pleospora rot, caused by *Pleospora lycopersici* Él. & Ém. Marchal, are responsible for some losses on green-wrap fruits during transit and ripening; these losses are usually of local importance only. With these last-mentioned diseases often there may be little evidence of disease in the field, but the fungi are present on the fruits and develop under the favorable humidity and temperature conditions during shipment and ripening.

RECOMMENDATIONS FOR CONTROL

Plant tomatoes in well-drained fields and plants will seldom suffer from these fruit rots. Generally there is little field injury except when rainfall is unusually abundant, and even then the damage is usually of only local importance. Avoid mechanical injuries in harvesting and packing the fruits as this will reduce losses in transit.

VIRUS DISEASES

Many of the more important virus diseases of tomato may occur wherever the crop is grown in the field, and some are common in the greenhouse. A few, such as curly top and spotted wilt, damage tomatoes only in regions where certain specific insect carriers (vectors) are abundant. Tomatoes, like tobacco, pepper, and certain other species of the family *Solanaceae*, can be infected with many plant viruses. However, some of these viruses do not occur commonly on the tomato.

In general, the symptoms of virus infection on the leaves consist of various types of mottling, curling, or distortion and, in some diseases, of spotting or withering of the leaflets. Certain viruses also cause a streaking of the stem that may kill the growing tips; with these the fruits at times are mottled, spotted, and misshapen. Some of these diseases may not always seriously reduce the yield and quality of the fruits; others stunt and damage the plant so severely that few, if any, marketable fruits are produced.

Tobacco (Tomato) Mosaic

Tomato mosaic, as the name is ordinarily used, refers to a virus disease commonly found in fields and greenhouses throughout the United States. It is caused by the virus causing the common mosaic of tobacco. Since it was first described on tobacco, the correct name is the tobacco mosaic virus. This virus also infects eggplants, peppers, petunia, and many other solanaceous plants and some plants of other families.

The ordinary green strain of the tobacco mosaic virus causes a light- and dark-green mottling of the tomato foliage and curling and slight malformation of the leaflets (fig. 29, *A*). During the winter months, however, leaflets of young plants grown under glass often are abnormally narrow and pointed. This symptom is known as "fern-leaf" (see fig. 36, *B*). Plants may be somewhat stunted if infected when small, but the plants and fruits are not much reduced in size if the plants are not infected until they reach the fruiting stage.

Certain yellow strains of this virus, which cause a striking yellow mottling of leaves (fig. 29, *B*) and sometimes a mottling of the stems and fruits (fig. 30), are often found. This yellow mosaic often causes distortion, curling, and dwarfing of the foliage and may greatly reduce the yield.

Other strains of the tobacco virus that may cause spotting of the leaflets and blemishes of the fruit are known to occur, but these have not been commonly found in the field and are of minor importance.

Although the common strains of tobacco mosaic virus may not always appear to markedly reduce the yield and quality of the fruit, they do lower the vigor of the plant. In the greenhouse the yields of plants infected after fruits have set may be reduced 4 to 5 percent as compared with yields of healthy plants. If plants are infected before any fruits are set, yields often are cut 10 to 15 percent. This loss occurs chiefly in the fruit of the first three clusters, which usually bring better prices than late fruits. Every effort should be made to prevent this virus infection or delay its appearance as long as possible. Prevention also is important because plants infected

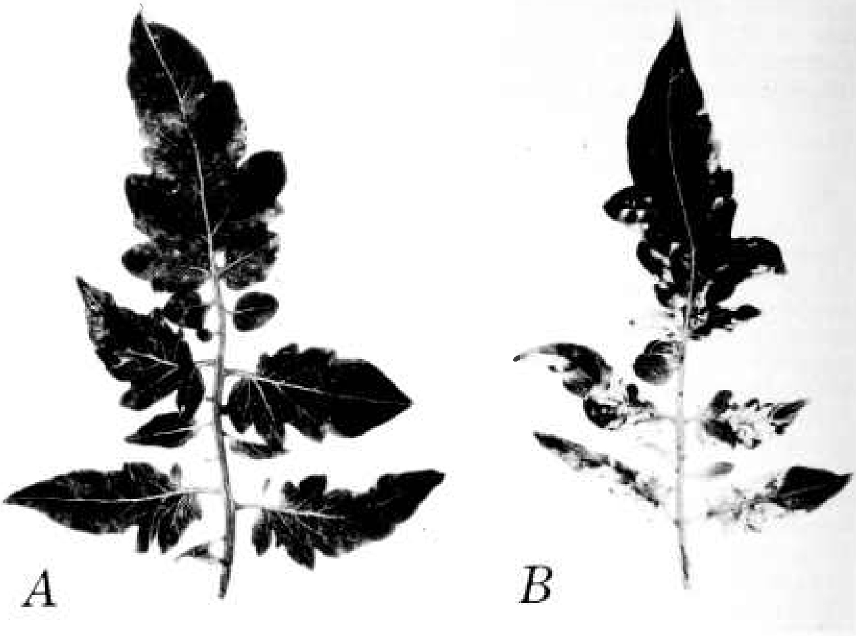

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FIGURE 29.—Tomato leaves showing symptoms of green (*A*) and yellow (*B*) strains of ordinary tobacco mosaic. The green mottling is much less marked than the yellow form.

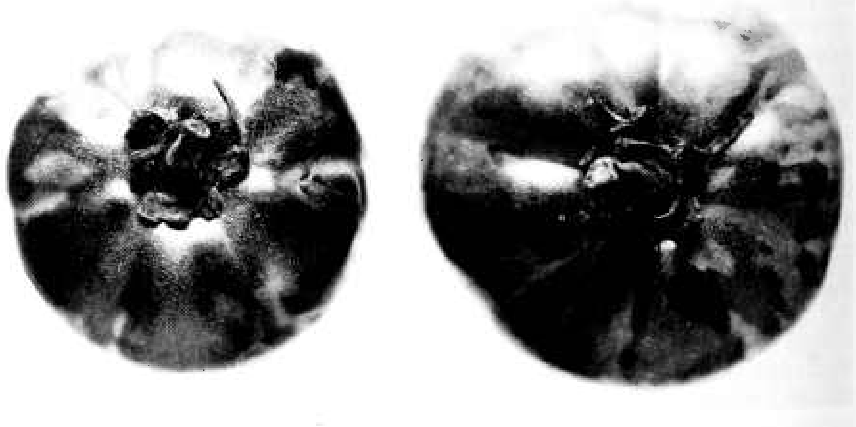

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FIGURE 30.—Tomatoes affected with the yellow strain of tobacco mosaic. These markings usually occur on the shoulders of the fruits.

with tobacco mosaic virus may also become infected with the potato-X virus. This combined infection causes a disease, double-virus streak, so severe that the plants are almost worthless (p. 42). Combined infections also occur with tobacco mosaic virus and other viruses, and the effect on the plants is more severe than those of either virus alone.

Tobacco mosaic virus is highly infectious and readily transmitted by any means that introduces even a minute amount of juice from a mosaic plant into a slight abrasion or wound in a healthy one. The virus is most commonly transmitted by handling mosaic and healthy plants in transplanting and by brushing against diseased and healthy plants during cultivation. Transplants grown by direct seeding in the field rarely are infected until after they have been handled in pulling, packing, and transplanting. In the greenhouse, plants are generally infected when they are pruned or tied. Because of the necessary frequency of these operations most greenhouse tomato plants are infected before the end of the season. The virus is also transmitted from mosaic to healthy plants by a potato aphid. This insect transmits the virus from tomato to tomato but not from tobacco to tobacco or tomato. Transmission by grasshoppers has been reported. Insects generally are less important than human agencies in the infection of tomato plants.

The virus of tobacco mosaic will live for several years in dried leaves and stems. In greenhouses, infection at times occurs from the remains of a previous crop of mosaic plants in the soil. This type of infection is most common where one crop of tomatoes is immediately followed by another. In the field the soil does not seem to be the source of much infection. The virus is also found on the surface of seed taken from mosaic fruits; if such seeds are planted almost at once after extraction, occasional seed transmission has been known to occur. In commercial practice, however, where the seed has been dried for some time before planting, there is little if any seed transmission of the virus.

Seedlings intended for field planting are often infected when grown in or near a greenhouse where the disease is present on older plants. This infection usually results from workers' handling the seedlings after working with the plants that are producing a crop, but it occasionally may occur through transmission of the virus by aphids. The tobacco mosaic virus also infects certain perennial solanaceous weeds such as groundcherry and horsenettle. It is possible that these plants may serve as sources of infection through the agency of aphids, which in feeding transmit the virus from the wild to the cultivated host.

The tobacco mosaic virus is present to some extent in cigar, cigarette, and pipe tobaccos. Therefore, smokers are likely to carry the virus on their hands. Probably most of the initial mosaic virus infection on tomato seedlings and plants in the field comes from this source. Tobacco manufactured for chewing or snuff carries little or no virus because of high temperatures used in their manufacture. Unprocessed "natural leaf" chewing tobacco is likely to have a high virus content.

RECOMMENDATIONS FOR CONTROL

To reduce losses from tobacco mosaic, the seedlings must be protected from infection. If mosaic transplants are planted in the field there is little that can be done to prevent the spread of the virus by the brushing against the plants by farm implements during cultivation and spraying of the crop. Roguing out mosaic plants does not usually check the disease in field plantings. To delay the spread of the disease in the greenhouse, remove diseased plants early in the season (p. 68). Certain practices will reduce the likelihood of seedling infection and help to delay a general infection with mosaic until the plants reach a size where the effect of the disease is not too severe. Follow recommendations given for sanitation and handling of plants (pp. 69 and 70.)

Experimental work indicates that, when the hands are dipped in plain milk or a solution of powdered milk, the number of seedlings infected after handling a mosaic plant may be much reduced. The hands must be dipped often enough to keep them wet with milk. This means of control is in the experimental stage and is not 100 percent effective. Milk inhibits the virus although it cannot cure an infected plant. Spraying seedlings with milk also has reduced, but not eliminated, infection by handling the plant. Protection by spraying lasts for only a short time.

Steam sterilization of the soil is one of the most important aids in controlling tobacco mosaic in the greenhouse. It is especially necessary in winter when plants for the spring crop are transplanted within a few days after the fall crop is removed. The virus persists for a time in the soil on the refuse of the preceding crop. In untreated soil, 10 percent of the plants set out within 3 to 10 days after the crop is removed may be infected. After 30 days there is usually little infection; however, the virus has been recovered from soil 9 weeks after the removal of mosaic plants.

However, winter sterilization of some soils is injurious to the plants. Therefore, if you have this type of soil, omit the winter sterilization. In such instances, inspect the plants and rogue for mosaic 2 weeks after transplanting and again a week later. Continue to inspect frequently (p. 68).

Internal Browning

Internal browning is a disease of tomato fruits that has caused severe losses in some tomato-growing sections of the eastern United States. The disease apparently is caused by late infection of tomato plants by the tobacco mosaic virus (p. 37). The symptoms seem to be indistinguishable from those of a disorder known as graywall (p. 58), which occurs in virus-free plants and apparently is caused by certain unfavorable environmental conditions.

The characteristic symptoms of internal browning are visible when the fruit is cut across one-quarter to one-half inch below the stem in order to expose the fleshy outer wall (pericarp) and the inner walls (septa) of the seed cells (locules). In slightly diseased fruits the tissues close to the vascular bundles are brown and corky (fig. 31, *A*). In severely diseased fruits much of the fleshy tissue of the wall is brown; the discoloration extends into the septa and sometimes into the central column. These symptoms may appear in small green fruits, but they are more common in those that are well developed.

External symptoms of internal browning vary with the maturity of the fruit. In small green fruits, external symptoms are rare. In larger green fruits that are severely affected, the gray or grayish-brown discoloration of the tissues of the outer wall is faintly visible through the translucent skin (fig. 31, *B*). This appears in blotches without well-defined margins, and the surface of such areas usually is somewhat flattened. The shoulders of such fruits often are slightly flattened. In ripe red fruits the symptoms range from a slight yellowing at the shoulder to large discolored areas that correspond to those on green fruits. These are usually yellow and the margins blend into the normal red of the remainder of the fruit. In severe cases the brown tissue of the wall may be visible through the skin. Sunken spots

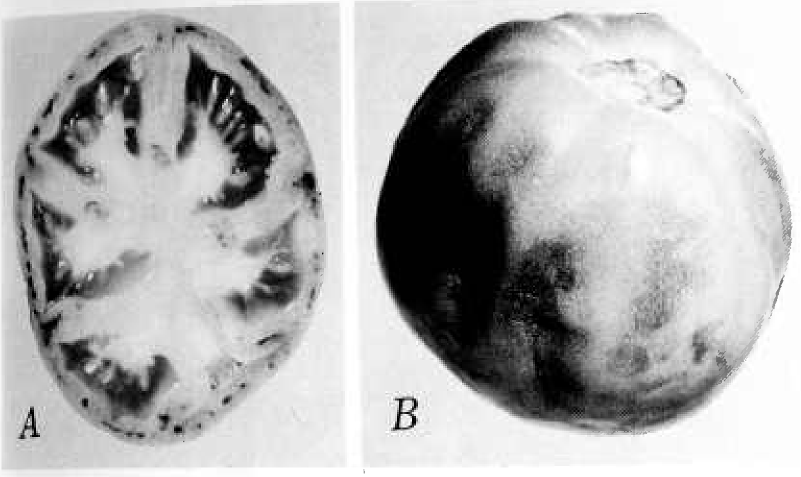

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FIGURE 31.—Tomato affected with internal browning: *A*, Cross section of tomato. The cells near the vascular bundles in the outer walls are discolored dark brown. *B*, Surface of same tomato. The blotches are dark brown and slightly depressed and the shoulder of the tomato is slightly flattened.

near the shoulders are common in ripe fruits.

There is evidence that internal browning is caused by infection of the plant by a strain or strains of the tobacco mosaic virus when the fruits are nearing maturity. At this time there appears to be a rapid accumulation of virus in certain fruits soon after inoculation. An extremely sensitive response by some of these fruits results in the development of internal browning. The disease occurs more often in plants growing under low light intensity at the time of infection with the tobacco mosaic virus.

RECOMMENDATIONS FOR CONTROL

To control internal browning, use the same measures that reduce infection by the tobacco mosaic virus (p. 37).

Double-Virus Streak

Double-virus streak, the most common and destructive form of streak, is caused by a combined infection with the ordinary tobacco mosaic virus and the so-called potato-X virus. This potato virus is found in nearly all, if not all, plants of the older standard varieties of potatoes grown in this country. It causes few or no visible evidences of disease in potatoes; and, when healthy tomato plants are inoculated with the juices from the tops or tubers of potatoes that carry it, only a very mild mottling appears on the foliage and no symptoms occur on the stems or fruits. However, if plants already infected with the tobacco mosaic virus are later infected with this potato virus, double-virus streak is the result. This disease often causes serious losses to greenhouse crops and is occasionally found in the field wherever tomatoes are grown.

The first symptom is a light-green mottling of the leaves, accompanied by the development of numerous small, grayish-brown, dead spots, which have a thin, papery appearance (fig. 32, *A*). Many of these leaves may wither and die in the early stages of the disease. The later growth is mottled green and yellow, dwarfed, and much curled, with small, irregular, chocolate-

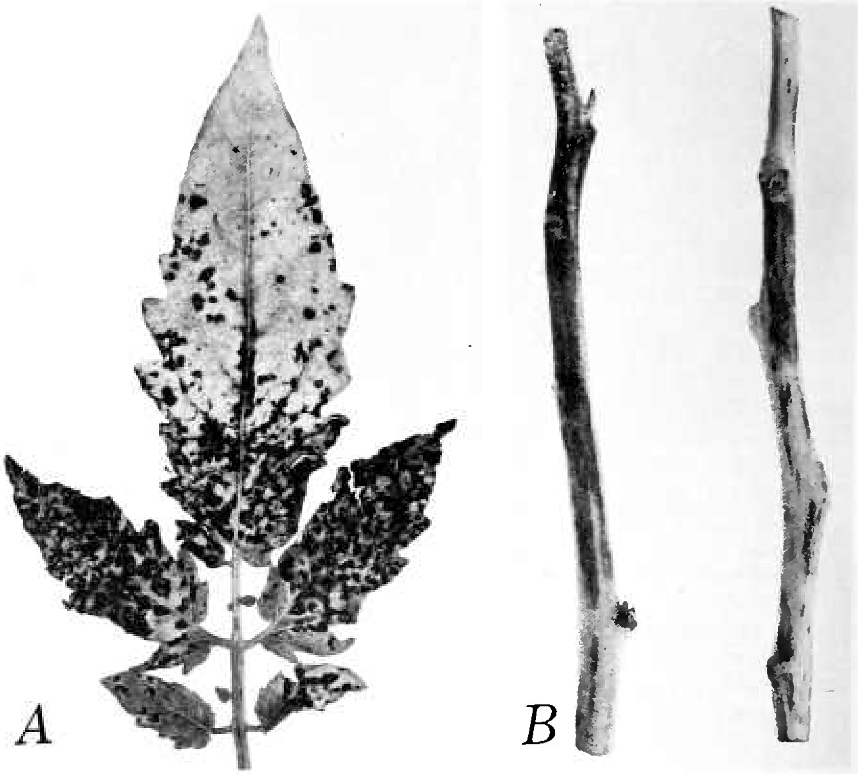

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FIGURE 32.—Tomato leaflets and stems showing early symptoms of double-virus streak: *A*, Leaflets covered with small spots that soon cause them to wither; *B*, stems showing streaks of different widths and lengths. The spots on the leaves are grayish brown; the streaks on the stems are dark brown.

brown spots scattered over the leaflets. Numerous narrow, dark-brown streaks develop on the stems and leaf petioles. This streaking gives the disease its name (fig. 32, *B*). It varies in severity. When plants are infected while small the tips occasionally die. Infected plants are stunted.

The streaked plants set comparatively few fruits. These fruits are often rough and misshapen and on the surface they have small, irregular, greasy, brown patches, one-eighth to three-eighths inch in diameter, which render them unfit for market (fig. 33).

There are several strains of the potato-X virus, which vary in the intensity of the symptoms they produce on certain hosts. The severity of the double-virus streak symptoms on tomatoes varies with the virulence of the strain of the potato-X virus with which they are infected. Some spotting of the leaves and streaking of the stem occur with all strains.

The potato-X virus is present in the tubers, and some of the initial infection in the greenhouse probably results from the virus being carried on the hands of the workers who cut or peel potatoes shortly before they tie or prune the tomatoes. In the field the potato virus may be transmitted to tomatoes by the hands, clothing, or tools of those

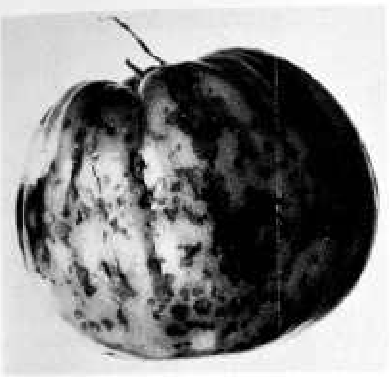

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FIGURE 33.—Tomato affected with double-virus streak. The spots are light brown and do not extend deep into the fruit.

who previously have worked in adjacent potato fields. When young plants are grown in the greenhouse for transplanting in the field, they may become infected from older plants in adjacent houses. The potato virus apparently is not spread by aphids. When once introduced into the greenhouse, the combined viruses are rapidly spread by those working with the plants. Serious losses usually result if streak appears early in the season.

RECOMMENDATIONS FOR CONTROL

Follow recommendations already given for preventing infection by the tobacco mosaic virus (p. 37). Since the tobacco mosaic virus is always present in streaked plants; and guard against infection of the plants with the potato-X virus.

To avoid such infection, wash your hands before starting to work with tomatoes if you have previously cut, peeled, or handled potatoes or worked with potato plants; your hands may carry the virus. Do not grow potatoes near the greenhouse nor plant tomatoes next to a potato field. Also do not plant tomatoes after potatoes (p. 67).

If the young plants in the greenhouses show symptoms of streak, remove them (p. 68). After the disease is well distributed throughout the greenhouses, however, this measure is of little value because plants recently infected carry the virus before showing any pronounced symptoms. Such plants often serve as sources of infection before the disease can be detected. Under these circumstances the new infections occur so rapidly that the removal of the diseased plants does not check the spread of the disease.

Although streak is hard to control when it occurs on plants large enough to be trellised, sometimes you can check the disease by roguing if it appears on only a few plants at very few points in the houses (p. 68). Then rope off the section of the house where double-virus streak is found and do not touch the plants for 2 weeks. If no more diseased plants are found, it is probable that all the infected plants were removed. This measure is effective only when the observer is familiar with the early symptoms of streak.

Single-Virus Streak

Another form of streak is occasionally serious in the greenhouse but is rather rare in the field. This disease is caused by a single virus much like that of tobacco mosaic. Single-virus streak is much less common than the double-virus type, and, when it occurs, the losses usually are less severe.

One of the symptoms is a green mottling of the leaves that is indistinguishable from that of tobacco mosaic. The infected plants may show no symptoms other than this mottling. But under some conditions that are not entirely understood the stems develop broad brown streaks; in such stems the pith shows brown shriveled areas, which are not found in plants affected with double-virus streak.

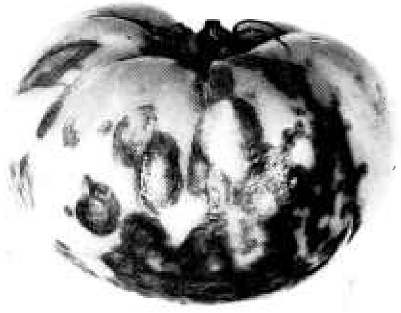

FIGURE 34.—Tomato showing the circular markings caused by single-virus streak.

The leaves of plants with stem streaks show small, irregular, dark-brown lesions or at times linear "oak leaf" markings; the later growth shows only a green mottling.

The fruits of the streaked plants may not be affected, but they often are marked with rather broad, depressed brown rings about one-half inch in diameter (fig. 34). This discoloration first appears as a slightly depressed, narrow ring on the surface of the green fruit and later changes to a broader brown marking. In ripe fruits there is no yellowing of the surface about these ring markings.

The virus, like that of tobacco mosaic, is spread by pruning or handling the plants. It does not appear to be commonly transmitted through the seed; however, it may live for a few months in greenhouse soil.

RECOMMENDATIONS FOR CONTROL

Follow recommendations given for preventing infection by the tobacco mosaic virus (p. 37). However, it is not known that single-virus streak occurs in manufactured tobacco. Follow recommendations for roguing diseased plants (p. 68).

Cucumber Mosaic

Wherever tomatoes are grown they may at times be infected with the virus causing mosaic of cucumbers and melons. Such infection is comparatively rare, partly because the cucumber virus, unlike that of ordinary tobacco mosaic, is not easily transmitted to tomatoes by brushing against or handling the plants. As this virus does not withstand drying, it will not persist in the soil and does not remain active for any great length of time on the hands or clothing. Therefore, most of the infection on tomatoes occurs through the agency of aphids. Such infection, however, is not common as the tomato is not a preferred host of the aphid that commonly feeds on cucumbers and melons.

There are several strains of the cucumber mosaic virus that produce symptoms on tomato; these vary in severity. Infected plants are usually considerably stunted. The internodes of the stem often are shortened; this makes the plants appear bushier and more compact than those affected with the ordinary tobacco mosaic virus. These plants set only a few fruits, and these are usually small.

The leaves show a milder green mottling than those affected by the tobacco mosaic virus, but they may be extremely distorted and malformed. Frequently the leaflets consist of little but a central rib and have a "shoestring" appearance, which is typical of this disease (figs. 35 and 36, *A*). This symptom in its extreme form seems to be characteristic only of certain strains of the virus. It does not occur in plants affected only with tobacco mosaic virus, but similar symptoms do occur in plants infected with tobacco mosaic and another virus that is not a strain of cucumber mosaic virus.

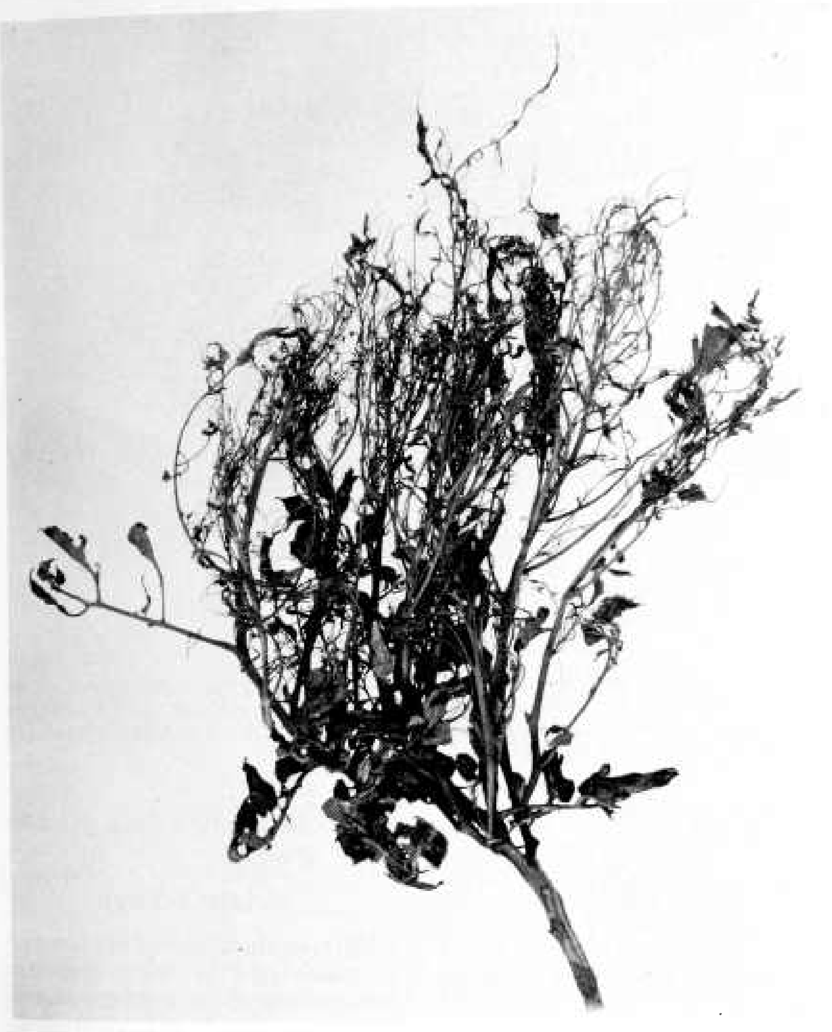

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FIGURE 35.—Tomato plant affected with the cucumber mosaic virus, showing extremely filiform ("shoestring") foliage.

The cucumber mosaic "shoestring" symptom is often confused with a symptom of tobacco mosaic known as "fern-leaf" (p. 37) (fig. 36, *B*). In "fern-leaf" the blade of the leaflet is not so completely suppressed as in a "shoestring" leaflet but is abnormally long and narrow.

Occasionally greenhouse plants infected with ordinary tobacco mosaic may later be further infected with the cucumber mosaic virus. Such plants remain short, and the leaves near the growing point show a peculiar bushy and upright habit of growth. The young leaflets are curled and distorted, and a few may show the "shoestring" malformations typical of cucumber mosaic. The older leaves show a mild mottle and a purpling of the veins and are rolled upward at the margins. Many of the blossoms are malformed and abortive, and the fruits

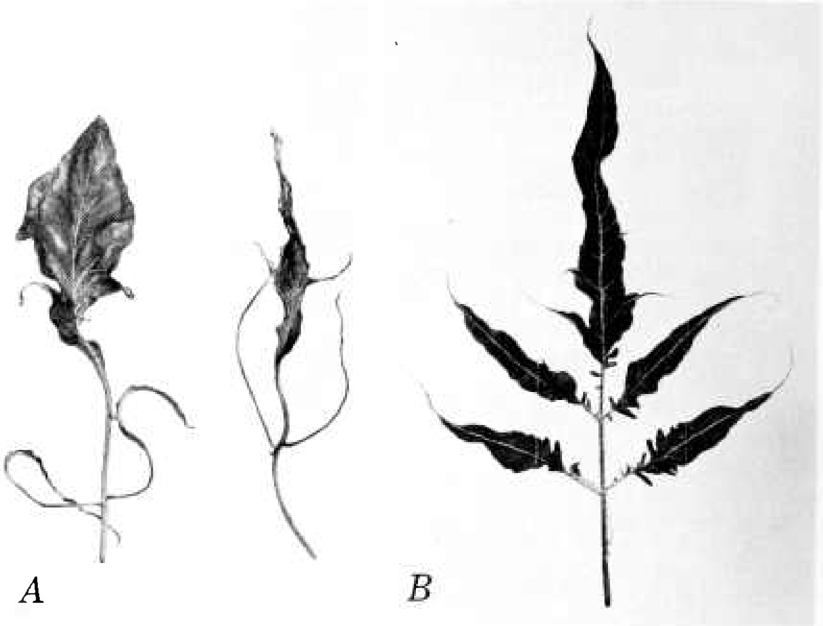

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FIGURE 36.—Tomato leaflets showing (*A*) the "shoestring" symptom caused by the cucumber mosaic virus and (*B*) the "fern-leaf" symptom sometimes found during the winter months on plants affected with ordinary tobacco mosaic virus. The "fern-leaf" symptom is not typical of cucumber mosaic.

produced are likely to be deeply ridged and to have protuberances at the blossom ends. This double infection occasionally causes serious losses on greenhouse tomatoes.

RECOMMENDATIONS FOR CONTROL

Control weeds and isolate tomatoes from disease-host plants (p. 68).

In the greenhouse, cucumber mosaic is not likely to damage tomatoes if its aphid carriers are controlled. Follow a regular program of control during the late summer and especially in the early fall, when aphids commonly begin to move into the houses from plants outside. Information on control of aphids can be obtained in U.S. Department of Agriculture, Agriculture Handbook 142, "Control of Insect Pests of Greenhouse Vegetables." Continue control measures at least until outside vegetation has been killed by frost.

Potato-Y Virus

The potato-Y virus (veinbanding mosaic virus) in recent years has become one of the most destructive virus diseases of tomatoes in southern Florida. It also causes serious losses on pepper in that area.

On tomato the first symptom is the development of dark-brown, dead areas in leaflets that are nearly mature. The tip leaflet of a leaf usually is most severely affected, but all may show this symptom. In this early stage of the disease the younger leaves show only a pronounced yellowing along the veins (fig. 37). Leaves produced after infection are slightly distorted and very faintly mottled. They curl down at the tips; the petioles also are curved downward; thus, the

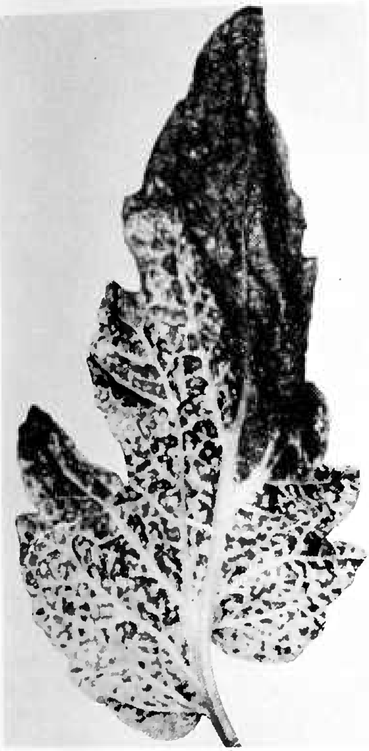

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FIGURE 37.—Leaflet of tomato plant affected with the Potato-Y virus. The veins are banded with yellow and part of the leaflet has been killed.

plants have a drooping appearance. Stems often show a purplish streaking, but the fruits do not show any symptoms. The plants are stunted and unthrifty in late stages of their growth, and yield is reduced.

Tomatoes frequently are infected with both the potato-Y virus and tobacco mosaic virus. This combination damages the crop more than either virus alone. Affected plants are severely stunted and produce few fruit. The leaves show a pronounced yellow mottling and are distorted in shape.

In Florida, different strains of the potato-Y virus have been found in various areas. The virus is frequently present in potatoes, and it appears that its initial appearance on tomatoes may have been correlated with the development of potato production in the areas where tomatoes are commonly affected. The virus is transmitted by a common species of aphid and has several weed hosts, which may be sources of infection to tomatoes after the disease has been prevalent on this crop for 1 or 2 years.

RECOMMENDATIONS FOR CONTROL

No effective control measures for the disease have been developed. Protect seedling plants from aphids by the use of insecticides. Avoid growing tomatoes close to potato fields.

Spotted Wilt

Spotted wilt is similar to the streak diseases in that it causes streaking or spotting of the leaves, stems, and fruits. However, it is more severe in its effect and, unlike the streak diseases, attacks many ornamental plants, weeds, and vegetable crops. The spotted wilt virus is transmitted by flower and onion thrips; although also transmissible by mechanical means, it apparently does not occur to any extent unless the insect carriers are prevalent. The disease has caused serious losses in some sections of California and in Oregon, where a very damaging strain of the virus causes what is known as tip blight. The disease occasionally occurs in the field in some of the East North Central and Atlantic States. At times it has caused serious losses on greenhouse crops.

On young, rapidly growing tomato plants, numerous small, dark, circular, dead spots first appear on the younger leaves. These leaves may have a peculiar bronzed appearance, and the badly spotted leaves may soon turn dark and wither (fig. 38).

The tips of the stems of such plants commonly show dark streaks, and the growing points frequently

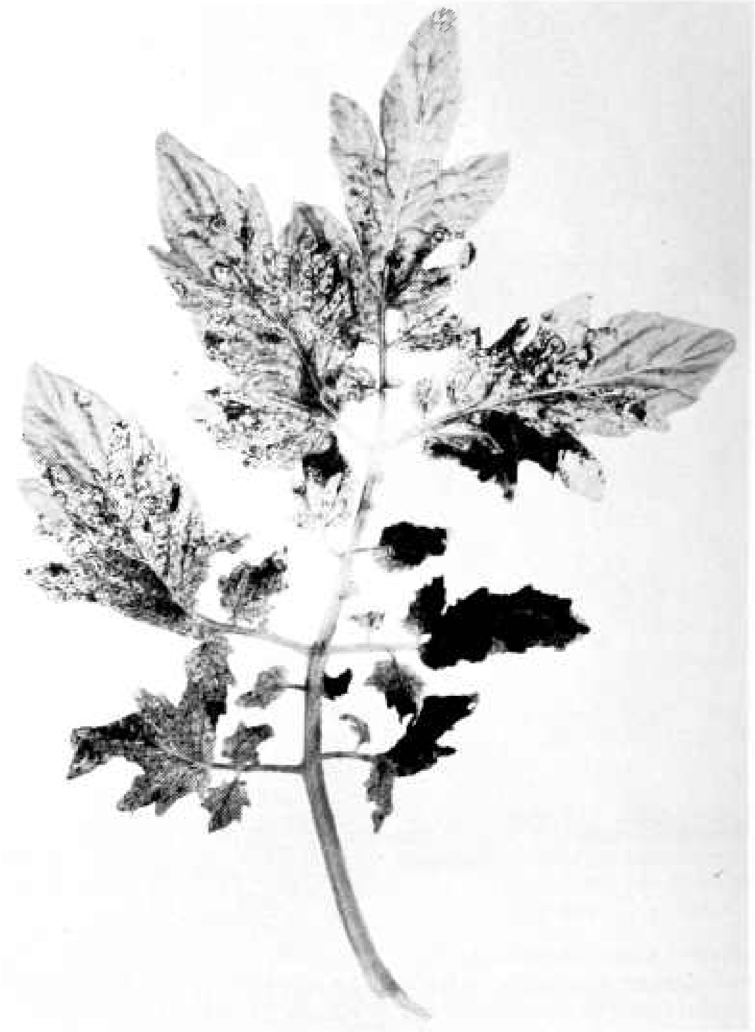

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FIGURE 38.—Leaf of tomato plant affected with the spotted wilt virus. The leaflets are covered with small dark spots and some have been killed. Such leaves often have a bronze color.

wither. Young plants may be killed; if they survive, the new growth is much dwarfed and the leaflets show a distortion similar to that caused by mosaic.

On older plants there is also more or less damage to the growing tips and the foliage may be somewhat yellowed. The fruits of these plants show numerous spots about one-half inch in diameter, with concentric, circular markings. On ripe fruits these markings are alternate bands of red and yellow (fig. 39). The centers of these spots often may be raised; this gives the fruit a rough appearance. The fruit symptoms are the most characteristic of the disease.

The spotted wilt virus also affects lettuce, celery, spinach, potatoes, and peppers and is found on weeds

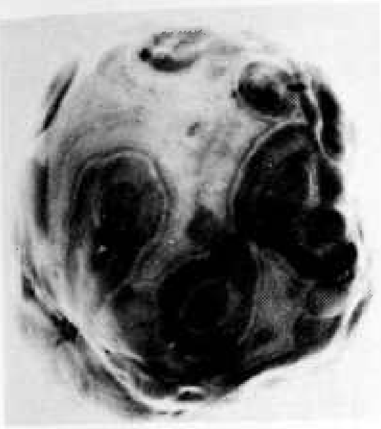

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FIGURE 39.—Tomato showing the concentric markings caused by the spotted wilt virus. On ripe fruit these consist of alternate zones of red and yellow. The spots give the fruit a rough appearance.

such as mallow, jimsonweed, and wild lettuce. It also affects many ornamental plants, particularly dahlias, calla lilies, nasturtiums, petunias, and zinnias. When these plants are infected with the virus they may serve as sources of infection for tomatoes if thrips are present. Dahlias frequently seem to be such a source of infection, especially when they are propagated in or near greenhouses where tomatoes are being grown.

RECOMMENDATIONS FOR CONTROL

For some protection, eliminate weeds and keep tomato fields isolated from host plants (p. 68). Remove tomato plants that show the disease when small, since, unlike those affected with tobacco mosaic, they can be replaced with healthy plants without the likelihood that these will be infected. Use insecticides regularly each week to control thrips.

Pearl Harbor, a rather early, red variety of determinate growth, is resistant to the strain of the spotted wilt virus found in Hawaii but not to some strains occurring in the United States.

Curly Top

Curly top, or western yellow blight, of tomatoes is caused by the virus that causes curly top of sugar beets. It is a destructive disease of tomatoes and often causes serious losses to other vegetable crops, particularly beans, table beets, spinach, squashes, and peppers. The disease is especially important on tomatoes and other vegetables in irrigated and dry farming sections of Utah, California, southern Idaho, and the eastern parts of Oregon and Washington. Some losses also occur on vegetable crops in certain sections of western Colorado and Texas, and the disease has been reported in Arizona, Nevada, New Mexico, Montana, and western Nebraska. In isolated cases the virus has been found in Illinois, Wisconsin, Maryland, North Carolina, and Kentucky on certain vegetable crops. In these States it has caused no appreciable damage to the tomato crop and the only known insect vector has not as yet been found in all of these areas.

The virus of curly top is not transmitted through the seed or soil, nor is it spread by contact of diseased and healthy plants or by the handling of plants by the grower. It appears to be disseminated only by a single insect species, the beet leafhopper (*Circulifer tenellus* Baker). This is a migratory insect that has its breeding grounds in weedy, abandoned lands and sagebrush sections of the semiarid region west of the Rocky Mountains. At times the disease assumes epidemic form in some sections of the Mountain and Pacific Coast States, and losses are severe. In those sections where leafhoppers are prevalent each year, it is almost impossible to grow profitable crops of tomatoes, beans, spinach, and

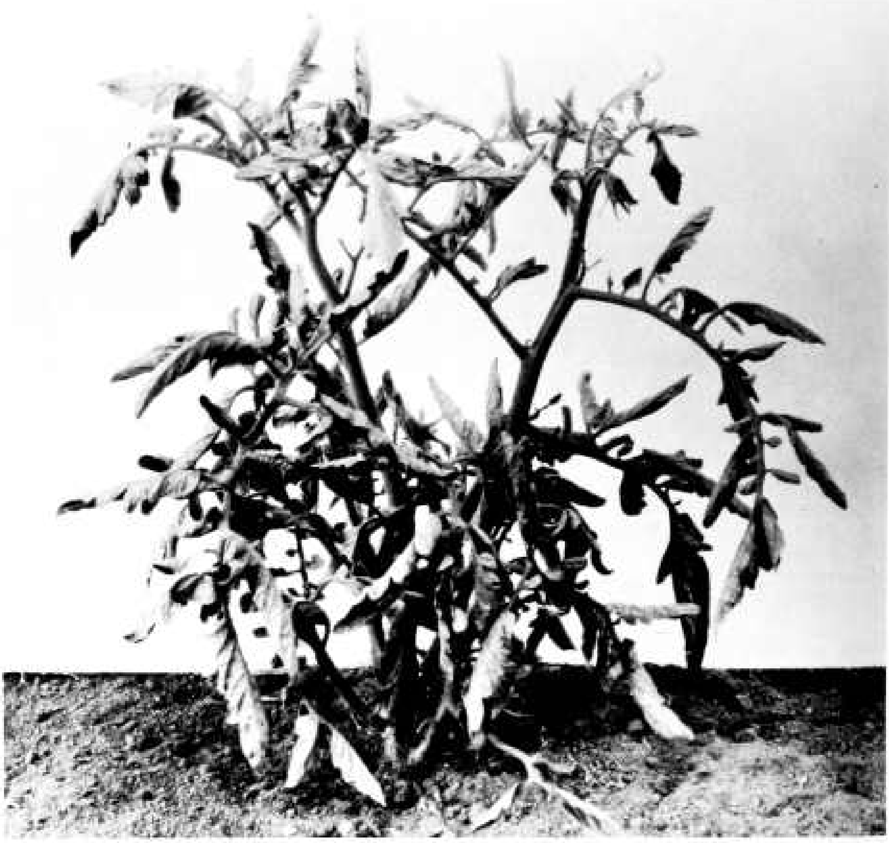

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FIGURE 40.—Tomato plant affected with the curly top virus. The leaflets are rolled upward, the leaf petioles have a downward curl, and the branches are abnormally erect.

other plants susceptible to curly top.

The tomato is susceptible to infection by the curly top virus at any stage of growth, but this susceptibility decreases markedly with increasing age of the plant. Infected seedlings soon show a yellowing of the foliage that may be accompanied by some curling and twisting of the leaves. Such plants ordinarily die within a short time.

On plants that are well established in the field, the first symptoms are a pronounced upward rolling and twisting of the leaflets that exposes their undersurfaces, stiff and leathery foliage, and a peculiar dull yellowing of the entire plant. The branches and stems become abnormally erect, and the petioles of the leaves curl downward. There often is some purpling of the veins of the leaflets, and the plant usually is much stunted (fig. 40). Many of the roots and rootlets are killed, and as a rule the plants gradually succumb. Very few, if any, fruits are produced after infection, and those that are already set turn red prematurely.

All the established cultivated varieties of tomatoes are severely injured by curly top. Early varieties appear to be killed more quickly than those that mature their fruit later in the season.

The leafhoppers become carriers of the curly top virus by feeding on wild or cultivated host plants that are affected with curly top. They then are able to transmit the disease to other plants for an indefinite period. The insects overwinter and produce their spring broods on various perennial and winter annual weeds and other host plants. Many of these hosts are susceptible to curly top and become infected through the feeding of overwintering leafhoppers that carry the virus.

When the spring broods of leafhoppers reach maturity, they migrate to weeds or other wild host plants that appear on uncropped or wastelands during the spring and summer or move to cultivated areas, where they feed on sugar beets and other susceptible crops or on weed hosts. This migration may be hastened by the maturing and drying of the plants on which the leafhoppers have bred in the abandoned or desert areas. Many of these migrating leafhoppers have acquired the curly top virus from breeding-ground hosts and transmit it to any susceptible plants on which they feed during the spring. Such hosts then serve as sources of the virus to the spring and summer broods of leafhoppers that develop on favored crop and weed hosts in and about the cultivated fields.

The severity of curly top in any given season depends on the number of insects carrying the virus to the cultivated crops and the stage of development of the crop at the time the insects feed upon the plants. A large influx of leafhoppers does not necessarily result in a severe epidemic of curly top unless a considerable percentage of the insects are carrying the virus. This is particularly true with tomatoes, since the tomatoes are not a preferred host and the leafhoppers do not breed on the plants. For this reason tomatoes are also more likely to be injured if grown near sugar beets or other favorable hosts of the virus and the insect, since the insects may spread in sufficient numbers from such hosts to inoculate many of the tomato plants with the virus.

RECOMMENDATIONS FOR CONTROL

As yet there are no very satisfactory methods for controlling curly top on tomatoes. The insecticide DDT is effective in killing the leafhopper, but it is not very effective in controlling the disease on tomatoes. This insect is difficult to control because of the great areas of its winter breeding grounds and the difficulty of controlling such a migratory sucking insect in the fields. Roguing of diseased plants also is of little value in reducing losses from curly top, since the disease is not transmitted by handling diseased and healthy plants.

Efforts are being made to develop resistant varieties by hybridization with wild tomato species that show resistance to curly top. The variety Owyhee, introduced in 1959, has shown considerable resistance to curly top in tests in Idaho. It is an indeterminate, red-fruited variety that warrants trial for the home garden and local market in areas where curly top is very damaging to tomatoes. Its commercial value remains to be determined.

Certain cultural practices have shown some value in reducing losses from the disease. Planting at such a time so as to avoid severe insect attack when the plants are small may reduce curly top infection in some seasons. However, no general recommendations can be made since the planting date must be adjusted to meet local climatic conditions and the probable time of migration of the leafhoppers cannot be accurately predicted. In some sections early plantings have given good results, and in others late plantings have suffered the least injury. Local experience is the best guide as to dates of planting.

The results of various experimental trials, particularly in Utah, indicate that closer planting distances in rows normally spaced will more or less reduce curly top infection and increase the yield of marketable fruit. These planting methods have consisted either in setting plants at even intervals as close as 6 inches or in double-hill plantings in which two plants are set at distances up to 6 inches apart in hills planted in rows 42 inches apart. As a rule the disease has decreased and the yield increased as the distance between plants has been reduced. However, the cost for plants and labor in transplating is much greater; and in years when curly top is not severe these increased costs may offset the gain from an increased yield. If a method of direct seeding in the field suited to the local environmental and cultural conditions can be developed to reduce the cost, such close planting is likely to prove of considerable value. Certain types of direct seeding have been in use in restricted areas for some time and apparently have given fairly satisfactory results in reducing losses from curly top, but further work will be necessary before any general recommendations can be made.

In home gardens, if labor and material required is available, shade the individual plants under slatted or muslin-covered frames. Another method, but somewhat less effective, is to cover the individual rows with tentlike strips of muslin. Support these by stakes or wires and anchor by covering the edges of the cloth with soil. With either method, lift the covers for weeding. Remove them when the plants touch the covers; after this stage of growth, injury from curly top usually is slight. The leafhopper prefers to feed on plants in the open; thus shading tends to keep the insects away from the plants. Shading also has an arresting effect on the development of the disease.

DISEASES CAUSED BY INSECTS AND NEMATODES

Psyllid Yellows

The disease known as psyllid yellows is caused by the feeding of the nymphs of a small sucking insect known as the tomato, or potato, psyllid (*Paratrioza cockerelli* (Sulc)). These insects secrete a toxic substance that is introduced into the plant during their feeding and causes serious abnormalities of growth. This disease, which also occurs on potatoes, has caused losses on tomatoes in Colorado, Utah, Wyoming, Nebraska, and other Western States. However, the injury to tomatoes, while sometimes severe in local areas, has not been of major importance.

The early symptoms of psyllid yellows consist of a thickening of the older leaves and an upward rolling at their base. The petioles of the younger leaves are twisted; the leaves turn yellowish green, with a purpling of the veins and margins. The younger leaves are narrower than normal ones and dwarfed and curl slightly upward at the tips. The stems and petioles are abnormally slender, and in older plants the internodes are lengthened, thus the new growth appears weak and spindling (fig. 41).

If the plants are affected when small, they commonly are much stunted and set few or no fruits. However, when plants are not attacked until they are well grown, there is often more than a normal number of blossoms. In such plants many fruits are set near the tips,

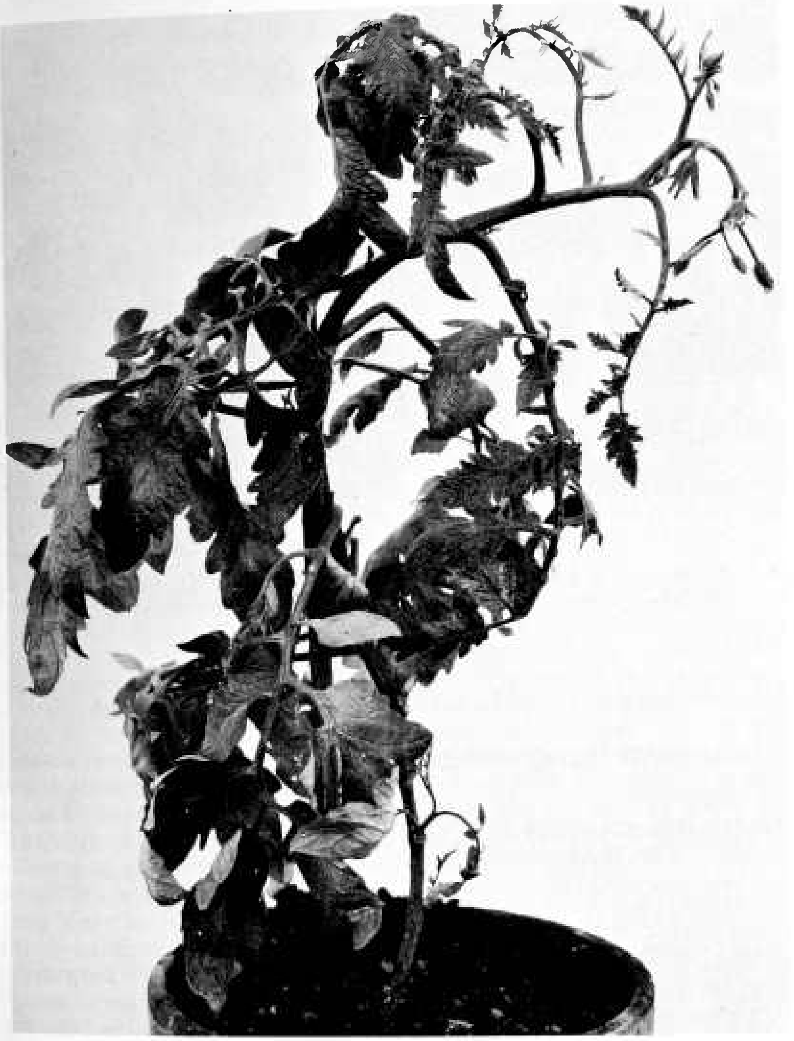

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FIGURE 41.—Young tomato plant affected with psyllid yellows. The leaves are twisted and somewhat narrower than those of normal plants.

but these do not develop to normal size. Plants showing marked abnormalities of growth usually produce yellowish-red fruits whose inner flesh also fails to color properly. These fruits are soft and of very poor quality. Plants that show only mild psyllid injury also are likely to produce inferior fruits.

The symptoms of psyllid yellows are suggestive of those caused by a virus disease and at times may be confused with those of curly top. However, plants affected with curly top show a more pronounced yellowing and curling of the leaves and die more rapidly than those suffering from psyllid yellows. No virus seems to cause psyllid yellows—the plants soon recover if all the psyllids are removed. This indicates that there is no increase of the toxin in the cells of the plant, as there would be if a virus were present.

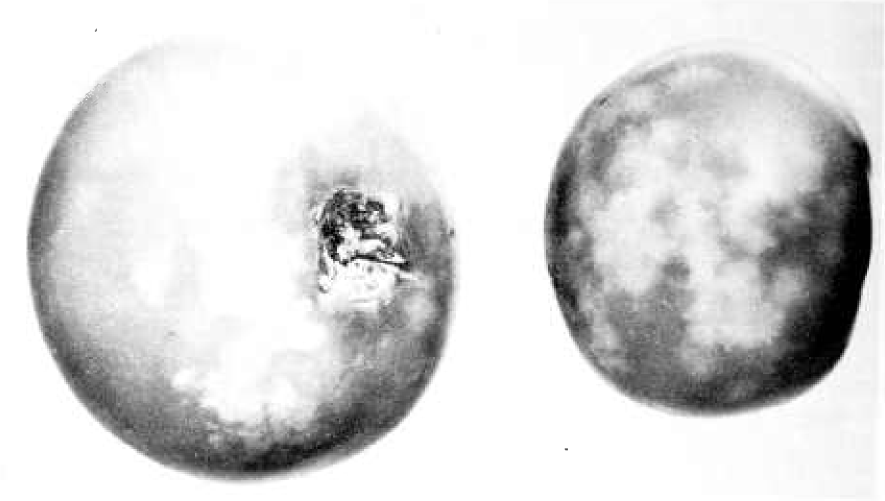

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FIGURE 42.—Tomatoes showing the whitish, irregular patches just below the skin that are called cloudy spots. These are caused by the feeding punctures of stinkbugs.

Further evidence against the virus theory is that no symptoms appear unless many insects are feeding on the plant.

RECOMMENDATIONS FOR CONTROL[4]

To control the tomato psyllid, dust the plants with 5 percent of DDT at 25 to 35 pounds per acre or apply a spray containing 2 pounds of 50 percent wettable DDT powder in 100 gallons of water at 100 to 125 gallons per acre. Treat the plants before symptoms appear. Make at least three applications; make the first one when the plants are about 6 inches high and repeat at 10-day intervals. With severe infestations, make five applications. As the nymphs of the psyllid inhabit the undersides of the leaves, cover these parts thoroughly with the insecticide. DDT is poisonous. Handle it with care. Follow the directions and heed all precautions on the container label.

Cloudy Spot

Tomatoes often show irregular, whitish to yellow spots in the tissues just below the skin. This condition, known as cloudy spot, is caused by the feeding punctures of certain species of insects of the pentatomid family, commonly called stinkbugs. Such spotting is often common locally in the Atlantic and Central States. Fruits showing these blemishes have a reduced market value, particularly for canning, because of their appearance.

The spots vary from one-sixteenth to one-half inch in diameter and may be so numerous as to cover a considerable part of the fruit surface (fig. 42). If the skin above such spots is peeled back, it will be found that they consist of glistening, white masses of cells with a spongy texture. These masses of cells do not extend deep into the fruit, and no decay of the tissues follows cloudy spot. Both green and ripe fruits are affected with this injury, but it is more apparent on ripe fruits, where the spots are light yellow.

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[4] Prepared by the Entomology Research Division, Agricultural Research Service.

RECOMMENDATIONS FOR CONTROL

As the disease occurs rather sporadically and is of minor importance, little has been attempted to control it. The amount of injury ordinarily does not warrant considerable expenditure for insecticides.

Root Knot and Other Diseases Caused by Nematodes

Wherever tomatoes are grown, both in the seedbed and the field, they are attacked and often seriously injured by various plant parasitic nematodes, or eelworms. Most of these are invisible except through a microscope. The female of the root-knot nematode is shaped like a pear and about half as large in diameter as the shank of a common pin; it can be seen as a white speck in infected roots, particularly when these are brown from decay. Nematodes live in the soil overwinter, or from one crop to the next, without feeding. When tomatoes are planted, they begin to feed on the roots and damage them in various ways in the process.

The root-knot nematodes (*Meloidogyne* spp.) causes the formation of knots or galls on roots. These range in size from smaller than a pinhead to an inch or more in diameter (fig. 43). The primary effect of feeding of the meadow nematodes on tomato roots is small brown lesions. These enlarge until the whole outer part of the root is discolored. Later some of the roots may rot. Similar effects are produced by several other kinds of nematodes and also by a variety of other kinds of organisms, so it is difficult to know whether or not the tomatoes are being damaged by nematodes. However, it is well to suspect nematode damage when the roots show knots or when the root system shows excessive rotting. The effect of nematode damage on the aboveground parts of tomatoes is also not distinctive. Since nematodes damage the root system, their general effect is to reduce growth and yield. Plants may be stunted and yellowish and wilt readily in dry weather or during the hottest part of the day. Very heavily infected plants may be nearly killed early in the summer while healthy plants continue to flourish.

Soil in which a nematode-infected crop of tomatoes has been grown will contain many nematodes at the end of the season, and these will live overwinter to attack a tomato crop planted the next year. Also, nematodes from other infected crops can attack tomatoes.

Nematodes from infested seedbeds will certainly be carried to the field with the transplants.

RECOMMENDATIONS FOR CONTROL

Once nematodes are introduced into soil, it is difficult or impossible to eradicate them. Avoid introducing them by carefully examining all plants for transplanting. If these show the knots caused by root-knot nematodes or the roots show excessive discoloration, destroy them, preferably by burning. Since most soils contain some plant parasitic nematodes that may damage tomatoes, treat all seedbeds with a nematocide (p. 75).

Unless a nematocide is to be used, avoid field soil on which crops infected with root-knot nematodes have been grown during the previous two seasons. Also, avoid using land that has been planted to tomatoes within the past 2 years, since it is more likely to contain large numbers of nematodes capable of attacking tomatoes than land that has not been in tomatoes. If the land is known to be infested with root-knot nematodes, use rotation crops

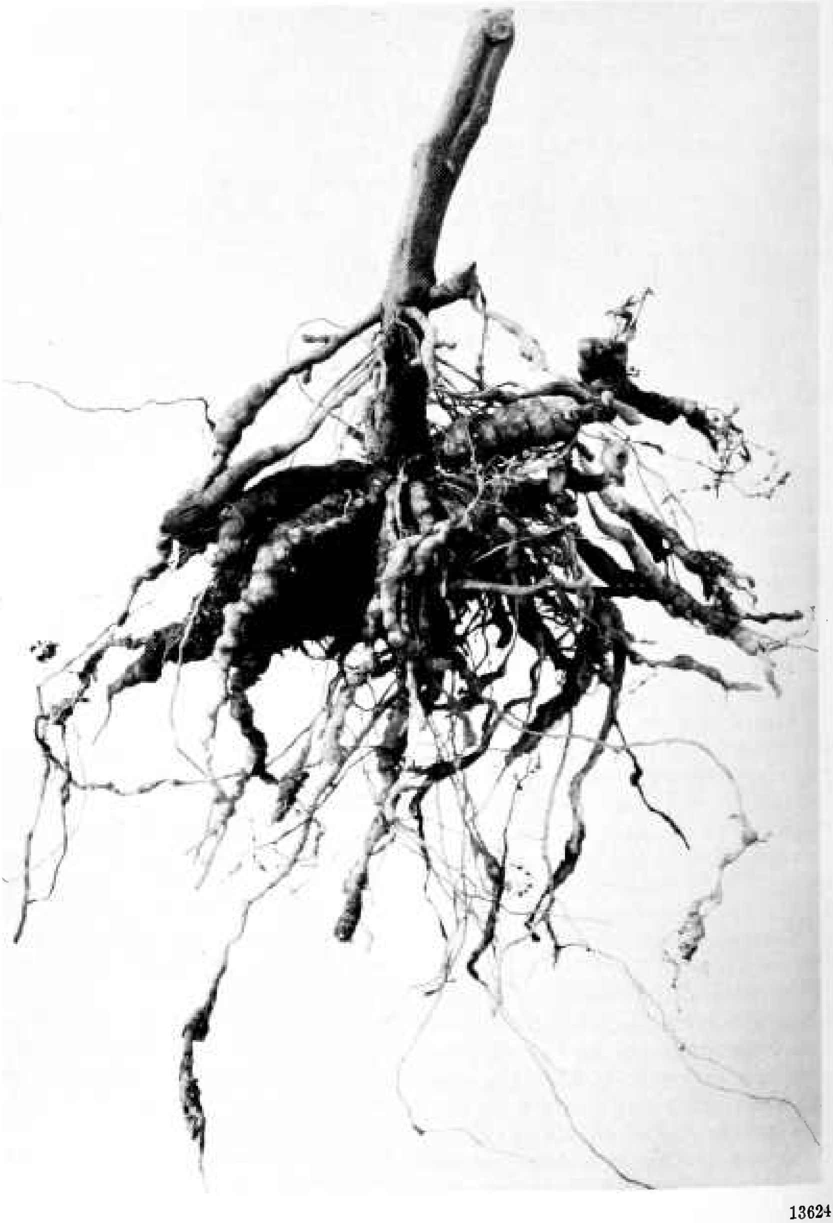

FIGURE 43.—Roots of a tomato plant showing the swellings, or galls, caused by infection by the root-knot nematode. The swellings may contain hundreds of these parasites.

known not to be attacked by root-knot nematodes in the vicinity. Since different species of root-knot nematodes occur in different parts of the country and farm crops vary with location, general recommendations cannot be given. Obtain advice on rotations from local county agents or State experiment stations.

All kinds of nematodes can be controlled by the use of nematocides (p. 75).

NONPARASITIC DISEASES

Blossom-End Rot

Blossom-end rot is a nonparasitic disorder of tomato fruit that occurs in both the field and greenhouse. At times there can be serious losses from the disease in certain fields and a trace of the disease is common in field plantings.

Fruits are most commonly affected when a third to half grown, but they may be attacked at any stage. The first sign of the disease is a water-soaked spot near the blossom end of the fruit. This spot becomes brown and enlarges until it may cover a third to half of the surface. As it increases in size, the tissues shrink; the surface of the spot becomes flattened or concave and dark and leathery (fig. 44). There is no soft rotting of the fruit unless the spots are invaded by bacteria or fungi.

Blossom-end rot occurs very commonly when the plants have grown rapidly and luxuriantly during the early part of the season and then are subject to prolonged dry weather at a time when the fruit are in an early stage of development. However, it can occur after periods of unusually abundant rain. Heavy application of nitrogenous fertilizers and extreme fluctuations in water supply are conducive to blossom-end rot.

A deficiency of calcium is the basic cause of the disorder. An excess of soluble ammonium, magnesium, potassium, or sodium salts—too low a supply of soluble calcium salts in proportion to the total soluble salts—lowers the calcium taken up by the plant. Addition of soluble calcium raises it.

Excessive total salts in the soil frequently is associated with blossom-end rot. This can be true even when the measured calcium seems high or at least sufficient. When salt concentration increases, the effective concentration of calcium salts available to the plant decreases more rapidly than that of other soluble salts. This reduces calcium uptake by the plant.

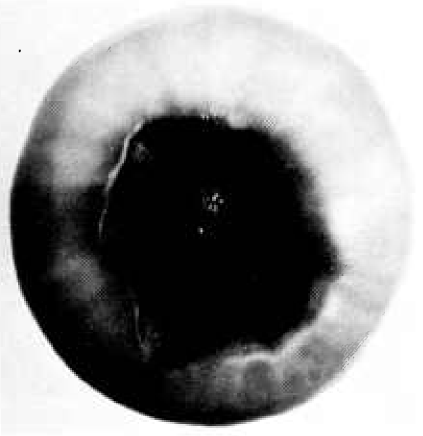

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FIGURE 44.—Tomato showing blossom-end rot. The tissues are dark and shrunken and the surface of the spot has a dry, leathery appearance.

Since calcium is not translocated from older to young tissues, even a temporary deficiency of this element in the soil solution can quickly cause injury to the developing tissue. The blossom-end of the young fruit is relatively low in calcium and especially subject to calcium deficiency.

In dry weather, soluble salts accumulate in the surface soil either by movement upward in the soil or from fertilizer side dressings. When rain moves these accumulated salts downward from the surface of the soil, the total salt concentration increases in the zone of effective uptake by the roots; and the calcium ratio is decreased. When soils remain excessively wet, the ammonium nitrogen accumulates and, as before indicated, can markedly reduce uptake of calcium and cause blossom-end rot. Very rapid vegetative growth, which often is associated with blossom-end rot, draws heavily on the supply of calcium and is thus a factor in the development of the disorder.

RECOMMENDATIONS FOR CONTROL

On soils known to be deficient in calcium, use lime and avoid an excessive use of commercial fertilizers, which contain the more soluble salts. Use gypsum, about 500 to 1,000 pounds per acre, or superphosphate, 500 to 1,000 pounds per acre, as a supplement to liming on calcium-deficient soils. Soils that have had frequent applications of lime and superphosphate usually accumulate a good supply of soluble calcium if they are not leached excessively.

After the tomatoes are planted, surface applications of lime or materials containing soluble calcium are not generally advisable. In areas where dry weather frequently occurs or where there are occasional prolonged and heavy rains, supplement the reduced supply of soluble calcium in the soil by spraying the foliage with anhydrous calcium chloride (4 pounds of 96 percent or 5 pounds of 78 percent per 100 gallons of water). Do not exceed these rates as the leaves can be burned if too high a concentration of the chemical is used. Calcium chloride of this concentration apparently can safely be mixed with most fungicides and insecticides used on tomatoes.

Foliage application is not a substitute for proper treatment of the soil to maintain an adequate calcium supply in the soil. It can only supplement the soil-calcium supply. Avoid prolonged use of calcium chloride as it can injure the foliage. When blossom-end rot appears or conditions seem to favor its development, spray the plants once or even twice a week while the unfavorable conditions prevail.

Graywall

Graywall is a disorder that may affect tomatoes wherever they are grown. It has caused serious losses in southern Florida and has occurred in several tomato-producing sections in the Central and Eastern States. The symptoms of graywall are so nearly identical with those of internal browning (p. 40) that the two cannot be distinguished with certainty on the basis of their symptoms. Graywall takes its name from the gray to grayish-brown blotches that develop on the surface of green fruits when there is internal browning of the tissues in the outer wall. The name "blotchy-ripening" also is applied to what appears to be the same disorder as graywall.

There is evidence that graywall may be caused by low light intensity, low temperatures, high soil moisture, and excessive compaction of the soil. The disorder is very common on the fruits from the interior of plants with very heavy foliage. In southern Florida, graywall is most prevalent in crops grown during the cooler part of the year. More affected fruits commonly are found on plants in very moist parts of a field than where soil moisture is only moderately high. Fruits grown on soil made compact by the passage of heavy machinery seem more subject to graywall than those grown in adjacent rows on less compact soil.

RECOMMENDATIONS FOR CONTROL

Possibly the disorder may be reduced by not using fertilizers that produce a very heavy growth of foliage and consequent shading of the fruit. Avoid, if possible, soils that regularly tend to be quite moist and cultural practices that tend to compact the soil.

However, the most effective means of preventing losses from graywall is to use varieties resistant

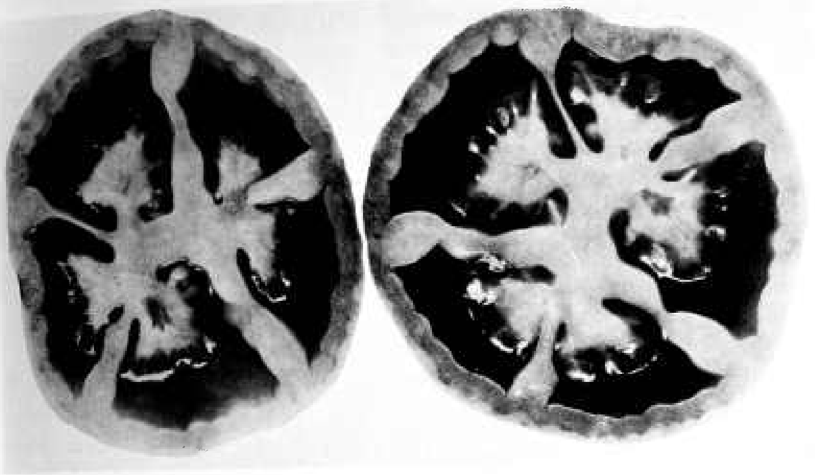

FIGURE 45.—Cross sections of tomatoes showing the cavities between the outer walls and the central parts of fruit affected with pockets.

to this disorder. The varieties Manalucie, Indian River, Ohio WR Seven, and Strain A Globe are quite resistant to graywall. Homestead, Jefferson, Rutgers, Fireball, and Grothen Globe are susceptible.

Pockets

Pockets, or puffiness, is a nonparasitic disease of tomato fruits that is most common on tomatoes grown for market during the winter and early spring. It causes considerable loss in the fields in Florida, Mississippi, Texas, and California and also occurs in greenhouse crops.

Affected fruits are light in weight and feel soft. They may be of normal shape, but often the surface is flattened or shrunken over the sections between the internal walls. When such fruits are cut in cross section, the fleshy, outer wall is usually found to be normal in thickness but the central part containing the seed is not fully developed and a cavity occurs between it and the outer wall (fig. 45). There is no discoloration of the flesh and no decay; but the fruits are unmarketable because of their soft texture and poor quality.

Pockets in tomatoes is apparently caused by various environmental and nutritional factors that either interfere with normal pollination or affect the later development of the seed-bearing tissues of the fruit. Both high and low air temperatures affect pollination. Both excess soil moisture and drought may possibly interfere with the normal development of the immature seeds and their surrounding tissues.

RECOMMENDATIONS FOR CONTROL

No definite control measures can be recommended. However, use ample superphosphate and only a moderate amount of nitrogen as this may help to prevent this trouble.

Blossom Drop

Tomato plants often fail to set a normal crop of fruit because of the dropping of the blossoms, which occurs at about the time the flowers are fully developed. This loss of blossoms may occur wherever tomatoes are grown and often causes a serious reduction in yield.

Several environmental factors probably cause blossom drop, but this trouble appears to be especially prevalent when the soil moisture is low and the plants are subjected to hot, drying winds. Such conditions appear to favor an abnormal elongation of the style, and few such blossoms set fruit. Sudden periods of cool weather or beating rains also may interfere with the proper development and fertilization of the blossoms, and excessive applications of nitrogenous fertilizers may be responsible for some dropping. Loss of blossoms also results from infection by parasitic bacteria or fungi, such as those causing early blight, septoria leaf spot, and bacterial spot.

RECOMMENDATIONS FOR CONTROL

Large-fruited varieties of the Ponderosa type are very subject to blossom-drop; therefore, do not grow these where summers are usually hot and dry. The varieties Summerset, Hotset, Summer Prolific, and Porter have been developed for freedom from blossom-drop in the hot, dry areas of the Southwest. When irrigation is possible, maintain an adequate but not excessive supply of moisture in the soil. Avoid excessive applications of nitrogen, especially during the early growth of the plant.

Sunscald

Sunscald may occur whenever green tomatoes are exposed to the sun, but it is most frequent during hot, dry weather. This injury is common on plants that have suffered a premature loss of their foliage from leaf-spot diseases, such as early blight and septoria leaf spot, and is a major cause of loss from these diseases. Fruits of plants suffering from verticillium or fusarium wilt also are likely to suffer from sunscald as a result of the loss of the lower foliage. Such injury is often severe in some irrigated sections of the West. Where healthy plants are irrigated too heavily or are irrigated rather heavily just before a rain, the amount of water in the soil may become excessive enough to kill much of the older foliage. This exposes the fruit to the sun, and the resulting losses from sunscald are often severe. Fruits of healthy plants may be injured if the plants are so disturbed as to expose the fruit to the sun during hot, dry weather.

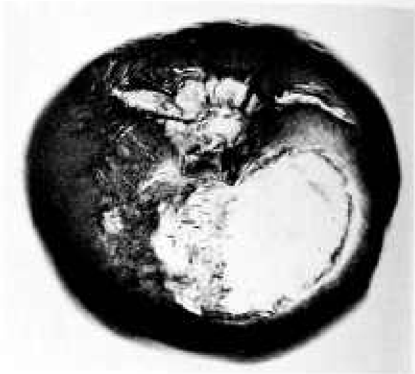

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FIGURE 46.—Sunscald-injured tomato, showing shrinkage and flattening of the discolored surface.

Sunscald is most common on immature, green fruit. At first a yellow or white patch appears on the side of the fruit toward the sun. This spot may merely remain yellow as the fruit ripens, but frequently the tissues are more severely damaged and a blisterlike area develops. Later this shrinks and forms a large, flattened, grayish-white spot with a dry paperlike surface (fig. 46).

Later such spots are frequently infected by fungi that produce a dark growth on the surface and sometimes cause an internal decay of the fruit.

RECOMMENDATIONS FOR CONTROL

Protect plants from defoliation by leaf-spot diseases and attacks of fusarium and verticillium wilts and there is likely to be little sunscald damage unless the weather is extremely hot and dry. Where fruits are exposed, put a very light covering of straw over the clusters.

Growth Cracks

Wherever tomatoes are grown, the surface sometimes cracks at the stem end of the fruit. These cracks may radiate from the stem (fig. 47) or extend more or less longitudinally around the shoulders of the fruit. The cracks vary in depth, but often they extend deep into the flesh. Where they develop slowly the surface tissue heals and becomes fairly firm, but it is likely to rupture readily in handling. These cracks are a blemish to the fruit and also provide points of infection for the organisms causing early blight and phoma and other rots of fruit.

This cracking of the fruit appears to be most common during periods of abundant rain and high temperatures that favor an extremely rapid growth. Another type of skin cracking also occurs in fruits that have reached the ripening stage during a period of dry weather. Then heavy rain and high temperature during ripening often cause a sudden splitting of the skin that extends either radially or longitudinally about the fruit. Varieties of tomato differ in their susceptibility to both types of cracking; some are characteristically subject to this injury.

RECOMMENDATIONS FOR CONTROL

When tomatoes are grown under irrigation, it usually is best not to apply water just before harvest as this may cause excessive cracking of the ripening fruit.

The varieties Campbell 146,

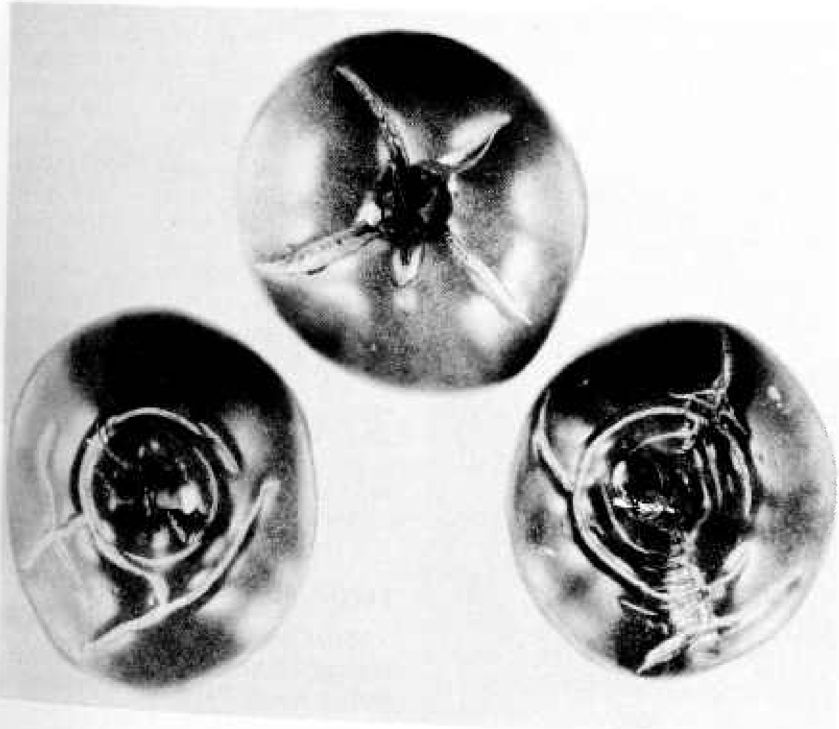

FIGURE 47.—Tomatoes showing growth cracks.

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Campbell 135, Chesapeake, Crack Proof Glamour, and Ohio Crack Resistant Red, are markedly resistant to cracking. Crack Proof has been used chiefly in breeding for resistance to cracking. Homestead 24, Jefferson, J. Moran, Manalucie, and Pearson Improved are reported to be relatively free from cracking.

Catface

Tomatoes frequently show extreme malformation and scarring at the blossom ends. This condition, known as catface, occurs to some extent wherever tomatoes are grown. The trouble is due to any factor that causes the tissues of the pistil of the flower to develop abnormally. The conditions causing certain plants to produce catfaced fruits are not entirely understood, but it is known that some varieties are especially subject to the catface injury. Serious disturbances to growth during blossoming, such as prolonged unseasonably cool weather, are believed to be related to such abnormalities of the fruit. Catface also is caused by injury from 2,4-D (p. 63).

Fruits with this abnormality are puckered and have irregular, swollen protuberances at the blossom end. Bands of scar tissue often occur between the swellings, and cavities that extend deep into the fruits are sometimes formed (fig. 48). Such fruits ripen unevenly. They are unfit for market because of their appearance and poor quality.

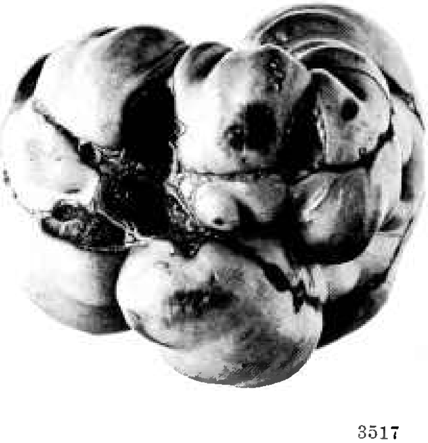

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FIGURE 48.—Tomato showing severe symptoms of catface.

RECOMMENDATIONS FOR CONTROL

No means of control for this trouble are known. Where it occurs to any considerable extent, grow a variety that is not subject to this abnormality. However, most of the standard market and canning varieties are not ordinarily subject to much catface injury except under very abnormal growing conditions.

Leaf Roll

During very wet seasons tomato plants frequently show an upward rolling of the leaflets of the older leaves. At first this rolling gives the leaflet a cupped appearance; it continues until the margins of the leaflets touch or even overlap each other (fig. 49). The rolled leaves are firm and leathery to the touch; one-half to three-fourths of the foliage sometimes may be affected. The growth of the plant is not noticeably checked, and a normal crop of fruit is produced.

The symptoms on tomatoes are very similar to those of a virus disease of potatoes that is also known as leaf roll, but the leaf roll of tomatoes is not caused by virus infection. Frequently leaf roll occurs when tomato plants are pruned severely, and it is very common when unusually heavy rains maintain an excessive amount of moisture in the soil for a prolonged period.

RECOMMENDATIONS FOR CONTROL

Since leaf roll usually does not severely damage the plants, its control is not a matter of serious economic importance. Plant tomatoes on well-drained soil as the trouble is less likely to occur there; how-

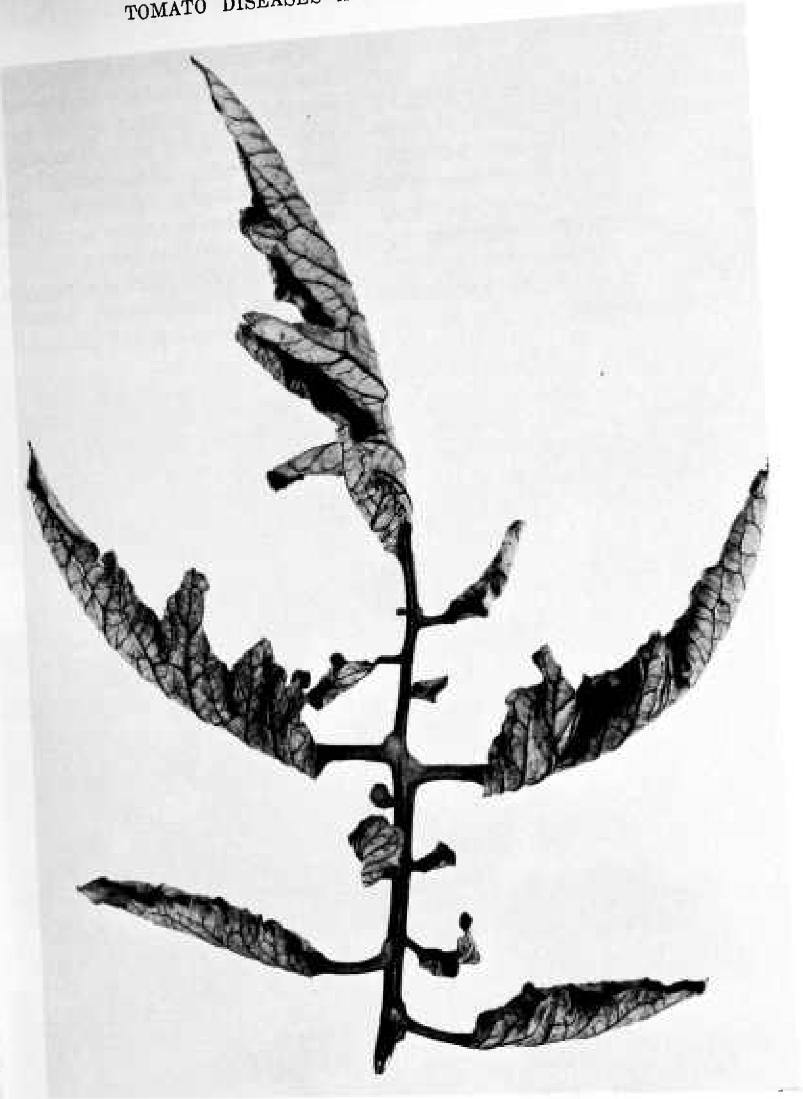

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Figure 49.—Part of a tomato leaf showing typical symptoms of leaf roll.

ever, it may occur on any soil during periods of continued and heavy rainfall.

2,4-D Injury

2,4-dichlorophenoxyacetic acid [2,4-D] is an effective herbicide for controlling many broad-leaved weeds in corn, small grain, grass pastures, fence rows, and in highway, powerline, and railroad rights-of-way and has been used extensively for this purpose. During the early years, many instances of injury to tomatoes and other sensitive broad-leaved crops were reported. Much of this injury was due to the use of highly volatile ester formulations of the herbicide in areas adjacent to sensitive crops. Present careful use of low-volatile ester and amine salt formulations of 2,4-D has greatly reduced the incidence of injury to tomatoes in commercial fields.

Tomato plants may be injured by spray drift of 2,4-D or by the use of a sprayer contaminated with the herbicide. Vapors from the ester formulations of 2,4-D may also drift with air movement and injure tomato plants. Injury varies with the amount of 2,4-D to which the plants are exposed.

The first symptom of injury is the downward curvature of the leaves and of the young growing points (fig. 50). If the plant is exposed to large amounts of the herbicide, severe curvatures of the leaves and stems, leaf roll, and general distortion of growth occur; this is followed by splitting of the main stalk and the formation of numerous small roots along the stalk. New

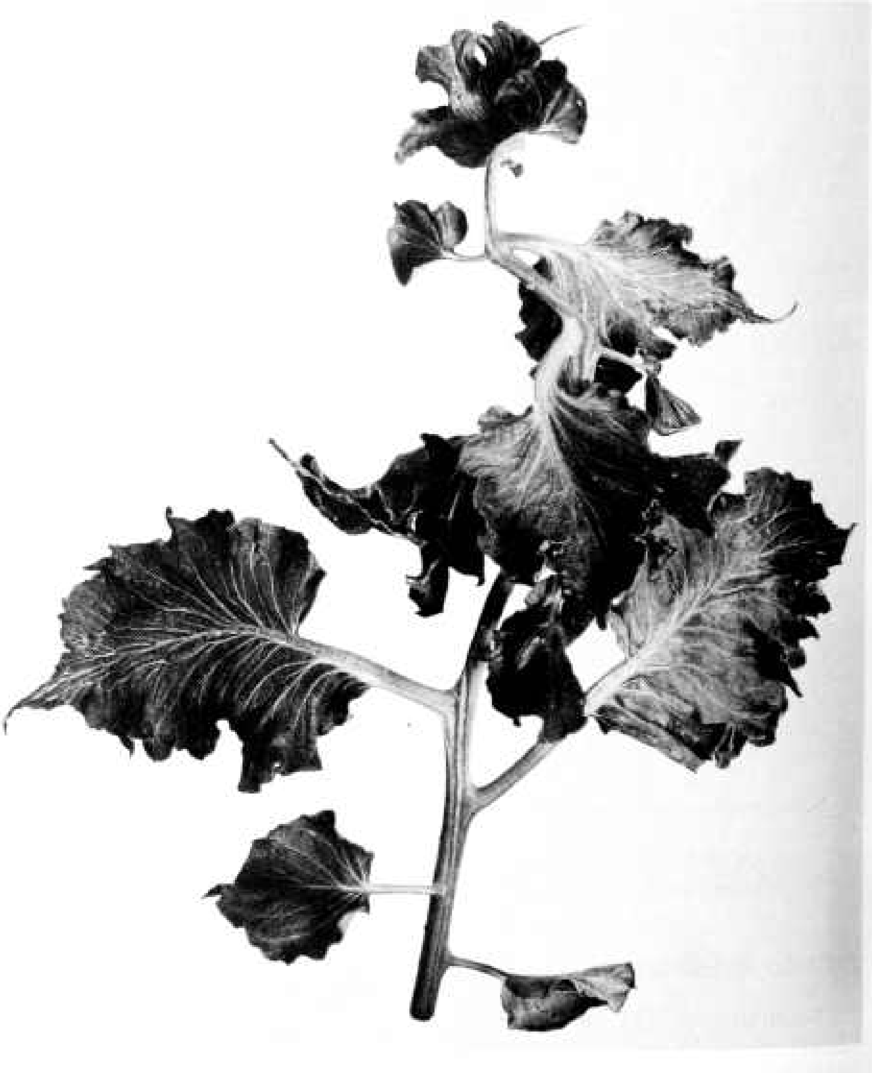

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FIGURE 50.—Tomato leaf showing characteristic moderate to severe 2,4-D injury. Downward curvature of young leaflets, prominent light-colored veins, rolled edges, distorted leaf surfaces, and sharp points of leaflets are evident.

leaves do not fully expand and they are twisted at the margins and are narrow and elongated with abnormally pointed tips; veins are prominent, light-colored, and appear parallel. Portions of the tissues between the veins are often raised in wartlike protuberances. Fruits that develop on affected plants exhibit the condition commonly known as catface because of incomplete closure of the fruit cavities. Very few, if any, seed are formed in these fruits. Exposed inner parts of the fruits remain green after outer parts have ripened. Tomato plants exposed to very small amounts of 2,4-D develop mild temporary leaf- and stem-injury symptoms that are outgrown without reducing yield or quality of the fruit; harvest, however, is often delayed under these conditions.

RECOMMENDATIONS FOR CONTROL

Observe the following simple rules in using 2,4-D to minimize the possibility of injury to tomatoes and other highly sensitive crops: (1) Avoid spraying when the wind may carry spray drift toward them; (2) avoid spraying when wind velocity exceeds 10 m.p.h.; (3) avoid spraying at elevations above surrounding sensitive crops; (4) avoid airplane applications in any area containing such crops; (5) use low-volatile ester or amine salt formulations; (6) use low pressure, preferably 30 p.s.i., and nozzle tips that produce a coarse spray to minimize spray drift; and (7) use a separate sprayer for herbicide applications.

If it is necessary to use the same sprayer for other agricultural chemicals, remove 2,4-D by the following procedure: (1) Rinse sprayer, including hoses and nozzles, several times with a mixture of ¼ pound of activated charcoal and ⅛ to ¼ pound of household detergent in 10 gallons of water; and (2) rinse sprayer several times with fresh water.

DISEASE OF UNDETERMINED ORIGIN

Fruit Pox

Fruit pox causes small pits on the surfaces of the fruits that seriously reduce their market value and furnish points of entry for bacteria and fungi. The cause of this disease is unknown. It has caused much damage to green-wrap fruits in Texas and occurs in Alabama, Florida, California, Illinois, and Wisconsin.

Small, dark-green spots that may be only specks and rarely are over one-eighth inch in diameter first appear. They are generally distributed over the surface, but often they coalesce and form streaks extending from the shoulder to the blossom end of the fruit.

The markings appear at an early stage of growth; as the fruit approaches full size, the spots usually become brown and are rough and corky. At this stage they may be either slightly raised or slightly sunken, forming shallow pits that give the disease its name (fig. 51). Occasionally the spots remain smooth and do not become brown; as the fruit ripens they turn yellow.

RECOMMENDATIONS FOR CONTROL

No control measures for fruit pox are known.

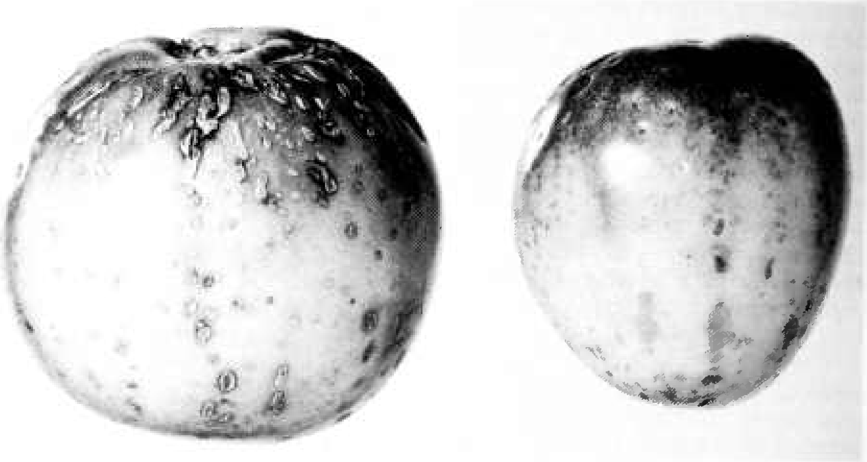

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FIGURE 51.—Ripe tomato affected with fruit pox. At some points the spots form streaks on the surface.

METHODS OF DISEASE CONTROL

Since nonparasitic diseases are caused by unfavorable soil or climatic conditions, the measures available for their control are largely good cultural methods and the use of fertile, well-drained soils. Parasitic diseases, however, may be controlled by using measures that destroy the parasites or prevent their spread. Control measures are described in this section, but their specific applications are given in the discussions of the various diseases.

Certain chemicals used for control of tomato diseases are referred to in this publication by coined common names, as follows:

Common name	*Chemical name*
Captan	N-trichloromethylthiotetrahydro-phthalimide
Dichlone	2,3-dichloro-1,4-naphthoquinone
Ferbam	Ferric dimethyl dithiocarbamate
Maneb	Manganese ethylene bisdithiocarbamate
Nabam	Zinc ethylene bisdithiocarbamate
Thiram	Tetramethylthiuram disulfide
Zineb	Zinc ethylene bisdithiocarbamate
Ziram	Zinc dimethyl dithiocarbamate

These chemicals are marketed under various trade names such as Stauffer Captan 50–W, Orthocide 50 Wettable, Orthocide 75 Seed Protectant, and Stauffer Captan 75 Seed Protectant for products containing captan; Phygon Seed Protectant, Stauffer Phygon XL–50–W, and Phygon XL for those containing dichlone; Fermate Ferbam Fungicide, Ferberk, Karbam Black, Coromate, Ortho Ferbam 76 Fungicide, and Miller Ferbam Fungicide for those containing ferbam; Manzate Maneb Fungicide and Dithane M–22 for those containing maneb; Dithane D–14, Niagara Nabam Solution, Parzate Liquid Nabam Fungicide, Ortho Nabam Liquid Spray, and Chem-Bam for those containing nabam; Arasan 75, Thiram 75 W, Arasan SF–X, and Chipman Thiram SF 75 for those containing thiram; Parzate Zineb

Fungicide, Dithane Z–78, Ortho Zineb 65 Wettable, and Parzate C Zineb Fungicide for those containing zineb; and Karbam White, Zirberk, Zerlate Ziram Fungicide, Orchard Brand Ziram, Niagara Z–C Spray, and Ortho Ziram 76 Fungicide for those containing ziram.

Before using any of these chemicals, see warning on inside of cover.

Use of Resistant Varieties

The use of resistant varieties is the most effective and also the most economical means of disease control, since it eliminates the labor and expense involved in other methods. For diseases caused by organisms living in the soil it is often the only feasible method of reducing losses.

There are one or more varieties with high resistance to fusarium wilt (p. 5), verticillium wilt (p. 6), late blight (p. 18), nailhead spot (p. 21), leaf mold (p. 32), and gray leaf spot (p. 33). Varieties with considerable resistance to early blight (p. 21), graywall (p. 59), blossom drop (p. 60), and fruit cracking (p. 61) also are available. Some of these have rather wide regional adaptation; others are suitable chiefly to the region in which they were developed. For controlling the majority of tomato diseases, however, no resistant varieties are available, and other methods must be used to reduce losses.

Use of Clean Seed

Certain bacteria and fungi causing tomato diseases are often carried by the seed. Most of this seed transmission results from surface contamination during the extraction process, but occasionally organisms attacking the fruit may penetrate the seed and be carried internally. This internal infection is comparatively rare, but it is of considerable importance with bacterial canker (p. 8). Organisms on the surface of the seed can be destroyed by chemical treatments, but such treatments have little effect on those within the seed. For best protection against such infection save seed from healthy plants or purchase certified seed. Several States now maintain an inspection service through which seed-producing fields of the more widely planted tomato varieties are inspected throughout the season for the presence of bacterial canker and certain other diseases. Seed meeting the requirements as to freedom from these diseases is given State certification. The common practice of saving seeds from fruits used for manufactured tomato products furnishes considerable protection from internal infection since badly diseased fruits are discarded in the manufacturing process.

Crop Rotation

The organisms causing many tomato diseases live for various periods on decaying organic material in the soil. Too frequent cropping with tomatoes tends to maintain these organisms and to increase their prevalence. Therefore, at least 3 or 4 years should intervene between crops of tomatoes in any field and 4 or 5 years where bacterial wilt has been prevalent. If bacterial wilt has occurred, do not grow eggplant, peppers, potatoes, or tobacco on the land during this interval. Do not plant tomatoes immediately after beans, beets, cabbage, celery, lettuce, peppers, potatoes, squash, sweetpotatoes, or watermelons on land where stem rot or southern blight has damaged these crops. Where the winters are not severe, let at least 2 years intervene between crops of potatoes and tomatoes in the same field; there is danger of infection from late blight, potato-X virus, and potato-Y virus from volunteer potato plants growing from infected tubers. In the Middle Atlantic and Central States, use 3- or 4-year rotations, especially with legumes and cereals, to avoid infection with the leaf spot fungus.

Rotation will not insure freedom from all diseases since several parasitic organisms are widely distributed in the soil throughout many tomato-growing areas and some, such as the fungi causing fusarium and verticillium wilts (pp. 2 and 5), persist for long periods after they are once introduced into the soil. However, rotation is especially important in retarding the development of these wilts, since continuous cropping soon builds up these organisms in the soil to a point that renders tomato production impossible if susceptible varieties must be used.

Isolation of Tomatoes From Disease-Host Plants

Many weeds, such as catnip, groundcherry, horsenettle, jimsonweed, mallow, milkweed, nightshade, pokeweed, and wild lettuce are hosts of certain fungi and viruses of tomatoes. These hosts serve as the source of infection through the agency of aphids, thrips, or other insects that feed on both the wild and cultivated hosts. Many such weeds along ditchbanks, roadsides, and other uncultivated land near tomato fields or greenhouses are infected. Therefore, keep down such weeds near seedbeds, fields, and greenhouses. Weed control must be general in the area to make it effective.

Do not plant cucumbers, muskmelons, celery, or peppers near greenhouses used for tomatoes. These crops are frequently affected by the cucumber mosaic virus, and aphids often carry the virus to the tomatoes. Also do not grow potatoes near the greenhouse nor plant tomatoes next to a potato field to guard against late blight, double-virus streak, and potato-Y virus. Where spotted wilt is prevalent, keep tomato fields isolated from home gardens and commercial plantings of ornamentals. Do not grow ornamentals in or near greenhouses used for tomatoes as certain ornamental species carry viruses, such as cucumber mosaic and spotted wilt.

Roguing of Diseased Plants and Disposal of Crop Refuse

In greenhouses, seedbeds, and small gardens, remove diseased plants as this is sometimes helpful in checking the multiplication of disease-producing organisms in the soil and preventing their spread to adjacent plants; but this measure is usually of limited value.

If plants in the greenhouse show symptoms of tobacco mosaic, double-virus streak, or single-virus streak, it may be possible to prevent an outbreak by roguing the diseased plants. This is usually effective only when a few plants show the disease when they are young. However, it is sometimes profitable, especially with double-virus streak, to rogue until the plants are 2 feet high. Inspect the plants frequently and remove and destroy those that show even the slightest symptoms before there is further handling of the plants. Take care not to brush the infected plants against healthy plants. This is difficult to do when removing plants that nearly touch each other. Therefore, when roguing larger plants, remove one plant on each side of the diseased one. Wash hands after removing diseased plants before handling healthy plants. (See also double-virus streak, p. 41.)

For disease control, always plow under all crop refuse immediately after harvest in order to prevent the parasitic fungi or bacteria that are present on diseased plants from multiplying. Plow deeply, as it tends to check the development of the organisms present on the remains of the diseased plants and so reduce the chances of later infection. In small gardens, collect the plants in the fall and burn them. Never mix refuse from garden or greenhouse crops with stable refuse or use it in composting soil, because such practices may introduce soil-borne organisms into fields.

Prevention of Diseases in Seedbeds

Wherever possible, start tomato seedlings in clean soil. If soil that has previously grown diseased plants must be used, thoroughly disinfect it with steam (p. 73) or a chemical disinfectant (p. 74) before planting the seeds.

Disinfect all flats, frames, sashes, and cloth covers with formaldehyde (p. 75). Whitewash applied to sashes and frames may be of some value as a disinfectant.

Before planting, disinfect the seed (pp. 70 to 72) and, if necessary, also treat for protection against damping-off fungi (p. 15).

In the greenhouse, a thorough program of sanitation helps to keep the transplants free from viruses. Do not start seedlings in a section of the house where there is any source of virus. Some viruses can persist on pots from one season to the next; therefore, sterilize them with steam. When potting seedlings, use new soil or soil in which tomatoes have not been grown for a year. Do not use potting soil that has grown tomato plants within a year unless it first is sterilized with steam (p. 73). Wash or steam-sterilize tools used to cultivate seedlings. Also thoroughly wash the hose. Do not take tools or hose to other houses where old infected plants are growing.

Handle plants as little as possible because handling may spread mosaic and other virus diseases if they are present on some of the plants in the seedbeds. Handling them when wet may spread bacteria or fungi from infected to healthy plants. To prevent infection with some virus diseases, such as tobacco mosaic, double-virus streak, and internal browning, wash the hands with soap and water before working with seedlings and do not smoke while handling the plants. (See also p. 40.) If you have been working where there are older plants infected with these or similar virus diseases you are likely to carry the virus on your clothing and infect the young plants. Avoid infection from clothing by having coveralls or other extra clothing to wear only in the plant house.

In greenhouses, coldframes, and hotbeds provide proper ventilation at all times as excessive humidity favors the development and spread of seedling diseases. Do not over-water seedlings especially during cool, moist weather. Water the seedbeds in the morning to insure more rapid drying of the leaves. Avoid frequent light sprinkling; apply water thoroughly at longer intervals. Do not crowd seedlings in the beds as doing this delays the drying of the foliage, which favors the spread of diseases.

Spray or dust the plants, as recommended, for early blight (p. 20), phoma rot (p. 26), bacterial spot (p. 26), and gray leaf spot (p. 32), to prevent serious losses from disease in the field.

Pull the plants for transplanting or shipment as soon as they reach a suitable size since the plants that are allowed to stand too long before pulling are likely to be more severely infected by the early blight fungus. If intended for shipment, pack the plants as soon as possible after pulling, as wilting seems to favor the development of early blight, collar rot, and stem-canker during transit.

Prevention of Diseases of Field-Grown Seedlings

In the South tomato seedings are grown extensively in the field for use in the northern canning States, and some field-grown seedlings are also produced locally in certain canning sections. To produce disease-free plants in the field, be as careful as to sources and disinfection of the seed as with plants grown in seedbeds or coldframes. Since field soils ordinarily cannot be disinfected because of the expense, it is extremely important to use land that is likely to be free from nematodes and from pathogenic fungi and bacteria. Select land that has not grown tomatoes or related crops for at least 2 years. Use a 4-year rotation where bacterial canker has occurred.

Do not grow seedlings in poorly drained fields. To prevent infection with certain diseases, such as bacterial wilt and bacterial canker, do not use land subject to surface drainage from fields that have been planted with tomatoes for 3 years.

In sections where the root-knot nematode is common, do not use a field known to have grown crops that showed noticeable symptoms of root knot (p. 55) or known to have been planted to crops susceptible to root knot. In many Southern States, tomato plants sufficiently free of nematodes for State certification are grown mostly on newly cleared land. However, plants substantially free of nematodes and otherwise of good quality can be grown on soil treated with nematocides (p. 75).

After the rough leaves appear, spray or dust the plants as recommended for plants in seedbeds (p. 69).

See also preceding section.

Cultural Practices for Prevention of Diseases in the Field

Certain cultural practices will help control some diseases. On calcium-deficient soils, use lime and supplement it with gypsum or superphosphate and avoid excessive commercial fertilizers (p. 58). This will prevent blossom-end rot. Also, the use of ample superphosphate and only a moderate amount of nitrogen will help to control blossom drop and may help to prevent pockets.

Where curly top is common, plant tomatoes at such a time so as to avoid insect attack (p. 51), set the plants closer in the rows (p. 52), and shade the plants (p. 52).

In small plantings, mulch the plants and, if economically practicable, stake them to reduce buckeye rot and soil rot.

When irrigation is possible, maintain an adequate but not excessive supply of moisture in the soil. This will help to control blossom drop. Do not apply water just before harvest as this may cause excessive cracking.

Seed Treatment

Seed treatments are used for two purposes: (1) To destroy disease-producing fungi or bacteria on the surface of the seed and thus to prevent seedling infection and (2) to coat the seed with a fungicide that will protect the seed and young seedlings against decay and damping-off caused by organisms in the soil (p. 15). Treatments that disinfect the seed surface do not necessarily protect against damping-off; therefore, a second treatment may be necessary to protect against damping-off fungi. It is essential to use the proper treatment for the purpose desired.

After treatment, take care not to recontaminate the seed by contact with untreated seed, contaminated bags, or other objects. **Before old cloth bags are used, sterilize them by boiling in water or soaking for 10 minutes in a 1 to 30 solution of commercial formaldehyde and then dry. Dry small quantities of seed on paper after treatment with liquid chemicals. If larger quantities must be dried on the floor, first disinfect the floor or thoroughly wash it with soap and water.**

Several disinfectant and protectant treatments are described in this section. Bichloride of mercury (below), ethyl mercury p-toluene sulfonanilide (Ceresan M) (p. 72), or hydroxymercurichlorophenel (Semesan) (p. 72) may be used for disinfecting the seed surface. Thiram, dichlone, and captan are good protectants against preemergence damping-off; they are not necessarily effective in disinfecting the seed surface.

Regardless of the treatment used, follow directions closely in order to obtain good disease control and avoid injury to the seed. **(Before using chemicals, see warning on inside of cover.)**

Bichloride of Mercury.—Bichloride of mercury (corrosive sublimate, mercuric chloride) in a 1 to 2,000 solution is an effective disinfectant against parasitic fungi or bacteria on the surface of tomato seed, especially against the organisms that cause bacterial canker and bacterial spot. It does not supply a chemical residue that protects against damping-off fungi in the soil. To obtain such protection, also treat the seed with thiram (p. 72), dichlone (p. 72), or captan (p. 72). However, do not use Ceresan M on seed that has been treated with bichloride of mercury.

In preparing the solution of bichloride of mercury, use only enamel, glass, earthenware, or wooden vessels, as the chemical corrodes metal containers. Bichloride of mercury may be purchased in the form of blue tablets or as a white, crystalline powder. The tablets dissolve readily in cold water and therefore are convenient for treating small quantities of seed; however, the powder is more economical for treating large quantities of seed. For a 1 to 2,000 solution, dissolve 1 tablet in a quart of water or 1 ounce of the powder in 15 gallons of water. Since the powdered chemical dissolves very slowly in cold water, dissolve it in about a quart of boiling water and then add to the remaining water necessary to make up the solution.

> When a considerable amount of seed is treated, it can be done in a commercial treater or in a homemade rotary drum. When using a homemade treater, fill the unit not more than half full of seed and rotate slowly for 2 minutes. Measure the chemical carefully and be sure the seed is uniformly coated. When treating a small amount of seed, fill a tight container half full of seed, add the proper amount of chemical, seal, and shake well for 2 or 3 minutes.
>
> Screen off excess dust immediately after treatment. Take care not to inhale the dust during or after treatment. Also follow any precautions on container label.

Do not treat more than one-fourth of a pound of dry seed in a quart of solution. Discard the solution after using it once as that weakens it.

Place the seed in the 1 to 2,000 solution and stir thoroughly for 5 minutes. Then pour it into a loosely woven bag, drain thoroughly, and wash for 15 minutes in several changes of water. Spread in a thin layer and allow to dry.

Freshly extracted seed may be treated in the same manner, but do not treat more than 1 quart of seed in each gallon of solution. Before treating the fresh seed, free it of excess water in order not to weaken the solution.

However, this soak method is not always practical with large quantities of seed.

Captan.—Captan (Orthocide 75 Seed Protectant and Stauffer Captan 75 Seed Protectant) is used as a dust for controlling preemergence damping-off. Apply it at the rate recommended by the manufacturer. Like thiram and dichlone, it does not seem to be so effective as mercury compounds for disinfecting the surface of the seed. Preemergence and postemergence damping-off may be reduced by wetting the soil immediately after planting with a suspension of 1 pound of captan (Orthocide 50 Wettable or Stauffer Captan 50–W) in 100 gallons of water. Apply 5 gallons to 100 square feet of soil.

Ceresan M.—Ethyl mercury p-toluene sulfonanilide (Ceresan M) is effective in disinfecting the seed surface against the organisms causing bacterial canker (p. 8), early blight (p. 18), nailhead spot (p. 21), phoma rot (p. 24), bacterial spot (p. 26), and anthracnose (p. 33). This treamtent also leaves a residue of the chemical on the seed that protects it against attacks of damping-off fungi in the soil.

Apply Ceresan M as a dust treatment at a rate of 0.5 percent by weight of seed. Use 8 ounces per 100 pounds of seed or one-half ounce per 6 pounds of seed (1 slightly rounded tablespoonful equals one-half ounce of Ceresan M). If seed is to be packaged in airtight containers, treat first and then dry to proper moisture for packaging.

Ceresan M is extensively used for disinfecting seed used for production of transplants in southern plant fields. It is somewhat volatile and the surface of treated seeds remain free from surface contamination for some time. Treatment with Ceresan M may slightly delay germination of some lots of seed; but this is offset by the benefits of the treatment, which has proved very valuable for disinfecting tomato seed.

Dichlone.—Preparations of dichlone (Phygon Seed Protectant and Stauffer Phygon XL–50–W) are used for controlling preemergence damping-off of tomato seedlings. Apply it as a dust at the rate recommended by the manufacturer. As a seed-surface disinfectant it is probably less effective than the compounds containing mercury.

Semesan.—Hydroxymercurichlorophenal (Semesan) can be used as a dust or a liquid treatment for control of preemergence damping-off of tomato seed. The liquid treatment checks preemergence damping-off and also acts as a rather effective surface disinfectant. Apply it as directed on the package.

Postemergence damping-off can sometimes be checked by sprinkling the soil with a suspension of 1 ounce of Semesan in 3 gallons of water. Apply this at the rate of 1 quart to 10 square feet of soil. ***Caution:* Do not treat the soil after the seedlings emerge.**

Thiram.—Thiram, used as a dust treatment, gives good control of preemergence damping-off of vegetable seeds. Apply at the rate recommended by the manufacturer. Thiram does not appear to be so effective a seed disinfectant as the organic mercury compound Ceresan M. It is not recommended for control of bacterial spot.

If seedlings in some parts of the beds show postemergence damping-off, its spread may be checked by watering these spots with 1 pint per square foot of a suspension of 1 level tablespoonful of thiram in 1 gallon of water.

Soil Sterilization and Disinfection

Disease-producing organisms frequently are present in greenhouse, seedbed, and hotbed soils; disinfecting such soils is a valuable means of disease control. To be effective, however, the treatment must be thorough and care must be taken to prevent recontamination of the soil. The methods commonly used are disinfection by steam or chemicals.

STERILIZATION BY STEAM

Treatment of soils by steam is one of the most effective means of sterilization; but its use is largely limited to greenhouses, since steam is not generally available for use with hotbeds and open seedbed soils. However, small, portable steam boilers are now manufactured especially for use in sterilizing small plots of soil.

In using steam be careful to prevent recontamination of the soil, since certain pathogenic organisms, particularly damping-off fungi, may multiply rapidly if introduced into freshly sterilized soil. Tomato plants at times may be damaged if transplanted into freshly steamed soil; therefore, allow 2 weeks or more between steaming and planting.

In the greenhouse, steam is most easily applied through a permanent system of tile 3 or 4 inches in diameter buried 15 inches in the soil in rows 18 to 24 inches apart. These tiles are attached to pipes that can be connected to a steam boiler. Steam is turned into the tile and maintained until the temperature at the surface of the soil reaches 210° F.

When such permanent systems are not available or seedbeds are to be sterilized, use a portable system. Usually a galvanized-iron pan 7 to 10 inches deep, 5 to 7 feet wide, and 8 to 12 feet long is used. Place this pan over the bed and force the edges into the soil to prevent the escape of steam. Then connect the outlet to a portable boiler or greenhouse steam line and, after the steam is turned on, leave the pan in place for 30 to 60 minutes; the time required depends on the character of the soil. For thorough penetration, the soil must be loose and moderately moist. After lifting the pan, cover the soil with canvas or burlap to retain the heat as long as possible.

Another method consists in burying perforated pipes in the soil in parallel lines and applying the steam from a connecting heater. The pipes are usually 1½ inches in diameter and have ⅛-inch holes drilled 1 foot apart in the bottom of the pipe. Bury them in parallel lines 1 foot apart at a depth of about 1 foot. When the soil reaches the required temperature lift the pipes and move them to a new location. The number and length of the pipes depend on the capacity of the boiler used.

Greenhouse benches and hotbed soils can also be sterilized with a steam rake. This apparatus consists of a frame of pipe to which are fitted rakelike teeth of perforated pipe that will extend 6 inches into the soil. These teeth usually are made of ½-inch pipe with ¼-inch holes near the closed ends. The frame is of such a width as to fit best the benches or frames. Bury the teeth in the soil and steam for 30 to 60 minutes with a cover over the area steamed. If canvas is not available, cover the soil with newspapers. Obtain a temperature of 210° F. at the surface of the soil.

In steaming for control of soil fungi or nematodes, it is often difficult to heat thoroughly the soil along runways and at the corners and sides of benches and frames. Steam sterilization is an expensive and rather laborious process; and, unless all the soil is thoroughly heated, the parasitic organisms may soon again be found infesting much of the soil. For this reason, take the temperature of the soil at the points mentioned to make sure that it is thoroughly heated.

DISINFECTION BY CHEMICALS

Certain chemicals are effective in destroying pathogenic fungi, bacteria, and nematodes in the soil. Some of these also destroy weed seeds. Materials effective against nematodes, bacteria, fungi, and weed seeds are usually too expensive for use in the field, but they are extensively used in seedbeds, greenhouses, and hotbeds. Those available include chloropicrin (Larvacide, Picfume), methyl bromide (Dowfume MC–2), sodium methyl dithiocarbamate (Vapam), and a mixture containing allyl alcohol and ethylene dibromide (Bedrench). Materials effective against nematodes only and inexpensive enough for widespread field use include formulations containing as the most effective ingredient ethylene dibromide (Dowfume W–85), dichloropropene (DD, Vidden D, Telone), or dibromochloropropane (Nemagon, Fumazone). **(Before using these chemicals, see warning on inside of cover.)**.

Since formulations vary, follow manufacturer's directions exactly.

Treatment with a formaldehyde solution is an older and more laborious method of soil disinfection than the use of these chemicals. It is used occasionally for disinfecting soil in small frames and soil in flats for greenhouse planting.

As of March 31, 1961 soil fumigants containing dichloropropenes were registered by the U.S. Department of Agriculture under the Federal Insecticide, Fungicide, and Rodenticide Act and the Miller Amendment to the Federal Food, Drug, and Cosmetic Act for use on soil to be planted to tomatoes to be grown to maturity. This registration is on the basis that no residue will result from use of 120 to 202 pounds of actual dichloropropenes per acre on ordinary soils or of 320 to 486 pounds per acre on muck-types soils if planting is not done until 2 to 3 weeks after treatment or until the odor of the chemical has left the soil. When nematocides containing ethylene dibromide or dibromochloropropane are used for soil treatment, there is a tolerance of 50 parts per million of inorganic bromide calculated as bromine. Further information will be found on the label of the nematocide or can be obtained from your county agent or from the manufacturer's representative.

Methyl bromide is registered for use on tomato plant beds only; therefore, do not grow tomatoes to maturity on soil treated with methyl bromide.

Chemicals for Seedbed, Greenhouse, and Hotbed

Chloropicrin. — Chloropicrin is very effective for killing fungi, bacteria, nematodes, and weed seeds in the soil. It can be used for disinfecting soil to be used in pots or flats, for soil in greenhouse benches, or for soil in ground beds. It is a liquid; apply it by injecting into the soil at a depth of 3 to 8 inches in lines 9 to 12 inches apart. Apply it with a special hand applicator or with an applicator attached to a garden or larger tractor. Follow the application with a "seal." This can be formed by sprinkling on enough water to wet the top inch or two of soil or by placing a plastic or other gastight cover over the soil. Wear a suitable gas mask for chloropicrin is a lachrymator (tear gas). The fumes in the air are toxic to plants; therefore, do not use it in greenhouses or other enclosed spaces where plants are growing. For the same reason, do not plant seed or transplants in soil treated with chloropicrin until all trace of the chemical has disappeared from the soil. This requires about 7 to 14 days in most soils, but it may take longer in cold, wet, or heavy soils.

Formaldehyde. — Formaldehyde is one of the chemicals used in disinfecting the soil. The so-called formaldehyde drench consists of a solution of 1 gallon of commercial (40-percent) formaldehyde in 30 gallons of water. Apply 1 quart of this solution to each square foot of soil. Do not apply it until the soil is fairly moist and in a loose and friable condition. After applying the solution, water the soil heavily and cover with a canvas or plastic cover; after 48 hours remove the cover to allow the gas to escape. As soon as the soil is sufficiently dry, work it to hasten the escape of the formaldehyde vapor. Do not plant for 10 days to 2 weeks. Never use formaldehyde where the vapor will reach plants, for they would be killed by the gas.

When a small quantity of soil is to be used in flats or benches, treat it with a solution of 1 part of formaldehyde to 5 parts of water. Apply one-half pint of the solution to each bushel of soil. Spread the soil in a thin layer and sprinkle with the solution, and then thoroughly mix and place in the flats or benches. Let the treated soil stand for 24 hours before planting the seed, and thoroughly water just as soon as the seed is planted. This treatment is quite effective in controlling damping-off, but it does not disinfect so thoroughly as the drench method. Do not transplant seedlings into soil treated by this method until the odor of formaldehyde can no longer be detected.

Drench flats, benches, or hotbed frames that are to be filled with sterilized soil with a solution of 1 part of formaldhyde to 30 parts of water. Let them stand for 48 hours before using.

Methyl bromide.—Methyl bromide controls bacteria, fungi, and weed seeds in the soil. It is a chemical having a boiling point of about 40° F. and is a gas at ordinary temperatures. It is obtainable in 1-pound cans and in cylinders containing larger amounts. Most formulations contain 98 percent methyl bromide and 2 percent chloropicrin, which is added to the odorless methyl bromide as a warning agent. Prepare the soil as for planting. Then place a plastic cover over it; bury the edges and support the center a few inches above the soil surface. Release the methyl bromide between the soil surface and the cover. Leave the soil covered for 48 hours. The soil can be planted the day after the cover is removed.

Sodium methyl dithiocarbamate.—Sodium methyl dithiocarbamate and materials containing allyl alcohol are applied as drenches after the soil has been prepared as for planting.

Nematocides for Field Use

Ethylene dibromide, dichloropropene, and dibromochloropropane are volatile liquids and are often referred to as soil fumigants. Commercial formulations may be diluted with naptha or other solvents, contain emulsifying agents, or be adsorbed on granules. The most efficient application method is similar for all; place material in the soil at a depth of 8 inches and immediately cover. If the whole area of the field is to be fumigated, place lines of the fumigant at intervals of 10 to 12 inches. For widely spaced crops, such as tomatoes, apply one or two streams of fumigant to the row only and leave the middles unfumigated. This saves half or more of the cost of the chemical. Application is usually by special applicators attached to tractors and is simple and easy once the applicator is adjusted. Materials adsorbed on granules can be applied by adaptations of some types of fertilizer distributors.

Follow the manufacturer's directions exactly and seek advice from local county agents or from State experiment stations as to the most efficient application methods and possible deleterious effect under local conditions. This is important because variations in soils and climates may affect the action of the chemicals.

***Warning:* Handle nematocides with extreme care. Avoid prolonged breathing of the fumes and do not allow the liquid to come into contact with the skin. If the liquid is accidentally splashed on clothing, including shoes or gloves, remove the garment without delay, and do not wear again until washed, cleaned, or at least thoroughly aired for a day or two. If it is splashed into the eyes, wash out with large quantities of water and consult a physician. Be sure that the material does not get into the mouth.**

Spraying and Dusting

VALUE OF FUNGICIDES IN DISEASE CONTROL

Losses from many leaf-spot and fruit-rot diseases can be greatly reduced by efficient spraying or dusting with the proper equipment. Good spraying is usually more effective than good dusting, partly because of better sticking of the spray on the foliage. Spraying is an increasingly general practice in commercial tomato production. However, efficient application of dusts can considerably reduce the loss from disease, especially when weather conditions are not extremely favorable to the development of fungus or bacterial diseases. **(Before using chemicals, see warning on inside of cover.)**

Some diseases occur in many localities every year, but they do not cause severe damage unless long periods of rain or very humid weather are accompanied by temperatures that favor the development of the causal organisms. Except for the late blight fungus, which requires cool weather for its rapid spread, the fungi causing the worst leaf diseases and fruit rots of tomatoes develop most rapidly at temperatures of 70° to 85° F. Losses from these diseases, therefore, are most severe when there are long periods of warm, wet weather. When the growing season is hot and dry, losses are usually slight.

Since conditions favoring extensive outbreaks of some tomato diseases do not occur every year, there are years when a reasonably profitable crop may be produced in some areas without fungicides and the added return from their use may not be large. However, certain leaf diseases have become more prevalent and destructive in regions where they formerly were of minor importance. Therefore, one faces a problem of potential loss from a number of diseases caused by fungi or bacteria. And, although all of these are not likely to be of serious importance in one region in any given season, some may cause severe losses if no control measures are taken.

Consider all these factors before planning a disease-control program. Fungicides, however, only prevent diseases—they do not cure them. Fungicides are needed as insurance against sudden outbreaks of disease. If the plant is not thoroughly coated with an effective fungicide when a long period of wet weather occurs, its leaves and fruit may be so generally infected that a later application of spray or dust will be of comparatively little value in preventing loss from disease.

Many new organic fungicides have been introduced and more are constantly being developed. Some of these are very effective against the organisms causing several tomato diseases. Others have a more limited range of disease control but are valuable for control of certain leaf spots and fruit rots of tomato.

For the most effective control, you may need to use more than one fungicide during the season or possibly to combine two materials in one application. Since the relative importance of some diseases may vary from year to year, control by fungicides may not be exactly the same each year. The climate in different regions also determines, to some extent, the number and relative importance of the diseases affecting the plants.

This publication lists the fungicides that seem to be most effective against each of the diseases described and the general methods for their effective application. No specific program can be outlined that will apply in all tomato-growing regions. Therefore, it is highly important to consult the county agent or State agricultural experiment station for the latest specific recommendations as to the fungicides best suited to tomato disease control in your locality and the most effective timing and number of applications.

TIMING THE APPLICATION OF FUNGICIDES

Spraying or dusting can be done most economically and effectively if the time and number of applications are determined somewhat by the amount of rainfall rather than by arbitrary fixed intervals between applications. In the field defoliating leaf diseases usually do not develop in severe form until the fruits begin to set. Unless weather conditions during the early part of the season are unusually favorable to the development of disease, make the first application of a fungicide about 30 days after the first cluster blooms. This occurs at about the time the plants fall over ("break"). In very dry years it may be possible to delay the first application somewhat longer. When the plants are grown under humid conditions that favor the rapid development and spread of certain organisms, usually begin spraying in the seedbed and continue it at regular intervals as soon as the plants are in the field.

Apply sprays at intervals of 7 to 10 days but if there are frequent rains, at intervals of 4 or 5 days. Apply dusts at 7-day intervals and more often during rainy weather. The number of spray or dust applications, therefore, will be determined to some extent by rainfall, but make at least five in the North Central and Middle Atlantic States and six to eight in wet seasons. In the humid South Atlantic States several more are often necessary. The number and timing of applications will vary somewhat with the diseases prevalent in any given season.

METHODS OF APPLICATION OF FUNGICIDES

Efficient power machinery is essential for spraying or dusting tomatoes, since their growth habit makes it difficult to cover the inner leaves and the fruit during the latter part of the season. Good coverage of the entire plant is necessary for disease control. Space the rows in a way that permits passage of the sprayer at proper intervals for good coverage. This spacing will depend on the type of sprayer used (see also p. 78).

In the past, when tomato fields were sprayed, the standard fixed-boom hydraulic sprayer was used. Usually three or four nozzles were used per row. Fungicide formulations, at the rate of 2 pounds in 100 gallons of water, were applied at a rate of 150 gallons per acre at a pressure of about 300 pounds per square inch (p.s.i.). This is equivalent to 3 pounds of fungicide per acre. When spraying seedbeds or very small plants in the field, use only 2 pounds of fungicide.

This type of application is still used with various modifications in the number and type of nozzles. It gives good control; however, 3 pounds of the fungicide can be formulated in as little as 40 gallons of water and this amount used to spray an acre with about as good results, if the equipment is properly adjusted and the spraying carefully done. This concentrated formulation is called a 4X concentrate, since it is approximately equivalent to 8, or more accurately 2½×3, pounds of fungicide in 100 gallons of water.

This so-called low-gallonage spraying is most commonly done with an air-blast (mist) sprayer (below). However, such a formulation should also give good results with a hydraulic fixed-boom machine, where all nozzles may be arranged in the same horizontal plane at a distance of 18 to 20 inches apart. The nozzles may be of the type that deliver a hollow cone or a flat (fan-shaped) pattern of spray. Either of these types of spray should overlap slightly at the upper level of the greatest leaf population. The pump pressure used to apply these concentrates need not be more than 100 p.s.i.

Air-blast sprayers are now being extensively used for spraying row crops. A concentrated formulation of the fungicide is introduced into a horizontal blast of air that is driven across the crop rows at high velocity. The air blast passes over the plants at such a level that some of the spray material is sheared off by the plant foliage as the air passes over it. In a sense, these machines are a compromise between hydraulic fixed-boom application and dusting. Most of this air-blast spraying is done with 4X or 5X concentrate (40 or 32 gallons per acre, respectively), although less concentrated mixtures can be used at higher gallonages with equally good results in terms of disease control. The spray mixture may be introduced into the air-blast at pump pressures as low as 60 p.s.i., with as good results as can be obtained with higher pressures.

For air-blast spraying, arrange the driveways so that there is an overlapping of the spray swaths in the center of the area between adjacent driveways. A machine with an air capacity of 20,000 cubic feet per minute and an outlet velocity of 90 to 100 miles per hour can spray a 35- to 40-foot swath satisfactorily. Therefore, arrange the driveways not more than 70 to 80 feet apart when such a sprayer is used.

Do not use air-blast sprayers when the wind velocity is over 7 to 8 miles per hour. Stronger winds will alter the swath pattern too much to permit good coverage of all the plants.

When fungicides are applied as dusts, use a power machine with two or three nozzles that discharge equal amounts of dust. Arrange these in such a way as to insure coverage of the entire plant. Dusters have been developed that discharge the same amount of dust when the supply is low in the hopper as when the hopper is full. Apply at least 50 pounds per acre. For good coverage of the plants, dust only when the air is quiet. Air conditions favorable for dusting often occur in the early morning or late afternoon.

FUNGICIDES FOR TOMATO DISEASE CONTROL

(Before using these chemicals, see warning on inside of cover.)

Bordeaux mixture. — Bordeaux mixture consists of copper sulfate and hydrated lime in water. As a fungicide it is equal to the fixed copper compounds, but it often injures tomato plants. The injury seems to result from an increased loss of water from the foliage, which appears to be caused by the lime in the mixture. Young plants are most subject to injury; seedlings sprayed with bordeaux mixture just before transplanting may wilt or die after they are set out. On large plants the injury is likely to be slight, especially when there is ample moisture in the soil.

Fixed copper compounds cause little injury to the plants and have largely replaced bordeaux mixture as a spray for commercial tomato plantings. It is occasionally used, however, as an emergency treatment for late blight (p. 18) late in the season. It also is used for control of the stem rot caused by *Botrytis cinerea* in greenhouses (p. 23).

When tomatoes are sprayed with bordeaux mixture, the most common formulas used are those known as 8–4–100, 6–3–100, and 8–8–100. The first figure indicates the number of pounds of copper sulfate, the second lime, and the third the number of gallons of water. Those with the lower lime content are thought to be less injurious to the plants. Apply bordeaux mixture at the rate of 150 gallons per acre.

All strengths of bordeaux mixture are prepared as follows except that different amounts of copper sulfate and lime are used. To make a stock solution, place 50 pounds of copper sulfate in a loosely woven bag and suspend it in 50 gallons of water in a wooden barrel. (Never use a metal container.) Suspend the bag high in the water overnight to dissolve all the chemical. Each gallon of stock solution will contain 1 pound of copper sulfate. To make 100 gallons of an 8–4–100 bordeaux, for example, add 8 gallons of the stock solution to 50 gallons of water in the spray tank; make 4 pounds of hydrated lime manufactured especially for spraying into a thin paste and wash through the tank screen with enough water to make 100 gallons. Vigorously agitate the mixture as you do this. Always use bordeaux mixture immediately after it is prepared, because it deteriorates on standing.

A finely powdered form of copper sulfate that dissolves rapidly in water and thus simplifies mixing is available. If this copper sulfate snow is used, place the required amount in the screen of the tank and dissolve it by running in enough water to fill two-thirds of the tank. Keep the solution agitated while washing in the lime paste with enough water to fill the tank.

The materials needed to make 3, 50, and 100 gallons of an 8–4–100 bordeaux mixture follow:

Material:	*3 gallons*	*50 gallons*	*100 gallons*
Copper sulfate	4 ounces	4 pounds	8 pounds
Hydrated lime	2 ounces	2 pounds	4 pounds
Water	3 gallons	50 gallons	100 gallons

Dichlone and ferbam.—Dichlone and ferbam appear to be the most effective fungicides against severe outbreaks of gray mold. However, neither controls late blight, which commonly occurs in the area where gray mold is a field problem. The following spray program is suggested for controlling gray mold.

When a variety resistant to gray leaf spot is grown and late blight is not present, apply dichlone (1¼ pounds per acre) every 5 or 6 days when temperatures are below 85° F. Substitute ferbam for dichlone on hot days, as dichlone will injure plants when temperatures reach 85°. Use 4½ pounds of ferbam per acre.

When varieties susceptible to gray leaf spot are grown or late blight is present, in cool weather spray with ¾ pound of dichlone plus 2¼ pounds of zineb per acre. Spray at 5- or 6-day intervals. Substitute ferbam for dichlone in hot weather, as previously described. The dichlone-zineb mixture is not equal to dichlone alone for gray mold control, but it will reduce losses from this and other foliage diseases except bacterial spot (p. 26).

Begin spraying when the plants are 3 to 4 inches high, as applications of dichlone must start very early in the season for satisfactory control of gray mold.

Fixed copper compounds.—The fixed copper fungicides are relatively insoluble forms of copper that are used without the addition of lime. They are effective against late blight (p. 16) and are used to some extent for the control of early blight (p. 18), phoma rot (p. 24), bacterial spot (p. 26), septoria leaf spot (p. 28), leaf mold (p. 30), and buckeye rot (p. 34). There are several fixed copper compounds that are sold under various trade names. Their copper content varies from 13 to 55 percent. Some of these formulations are as follows:

- Basic copper sulfates:
  - 53 percent copper. (Basi-Cop, Tennessee Tri-basic Copper Sulfate, Duo Copper, and Orchard Brand 530.)
  - 26 percent copper. (Corona "26" and Tennessee 26.)
- Copper oxychloride sulfate: 55 percent copper. (Niagara C-O-C-S.)
- Copper calcium oxychloride: 46 percent copper. (Dupont Copper-A Compound.)
- Copper hydroxysulfate: 13 percent copper. (Copper Hydro Bordo.)

As field sprays for tomatoes the fixed coppers are prepared on a basis that gives an equivalent of 3 pounds of copper (calculated as metallic copper) per acre. When applied at the rate of 150 gallons per acre, this is equivalent to 6 pounds per acre of a compound containing 50 percent copper. This concentration also may be used to spray the seedbed soil after planting for the control of damping-off. Apply about 5 gallons for each 100 square feet of soil.

The copper content of the different compounds is shown on the package, and the amount of material needed can be calculated from that figure. For example, 8 pounds of a compound containing 25 percent of copper would be needed to give 2 pounds of copper in 100 gallons of spray, whereas only 4 pounds of one containing 50 percent of copper would be needed. Before using the fixed copper compounds, consult your county agricultural agent or State agricultural college workers as to the compounds that have proved most effective under local field conditions.

A fixed copper compound combined with maneb substantially reduces buckeye rot infection. Use 1½ pounds of maneb plus 3 pounds of a 50 percent (actual copper) fixed copper compound per acre.

A fixed copper compound combined with streptomycin (p. 81) gives good control of bacterial spot. A fixed copper compound combined with ziram or in alternating applications with ziram (p. 81) is effective for controlling anthracnose, leaf mold, and late blight.

The fixed coppers also are used as dusts and seem to be fairly satisfactory. Dusts containing 5 to 7 percent of actual copper are recommended for tomatoes, 7 percent is preferable.

Maneb.—Maneb is a very effective fungicide for control of tomato diseases. It is especially valuable for controlling anthracnose (p. 33) and gives very satisfactory control of late blight (p. 16), early blight (p. 18), nailhead spot (p. 21), phoma rot (p. 24), septoria leaf spot (p. 28), leaf mold (p. 30), and gray leaf spot (p. 32). As a spray, use 3 pounds of maneb per acre.

Maneb combined with a fixed copper compound reduces losses from buckeye rot (p. 34).

Dusts containing 6 to 7 percent maneb also may be used for controlling these diseases, but spraying is preferable.

Nabam.—Nabam plus zinc sulfate gives good control of late blight (p. 16) and is fairly effective against early blight (p. 18), nailhead spot (p. 21), phoma rot (p. 24), and gray leaf spot (p. 32). Nabam is used in liquid form. Use 3 quarts of the commercial product to 100 gallons of water. Then add 1 pound of zinc sulfate dissolved in water to the solution. When this formula is followed, the reaction product is similar to zineb (below). Apply 150 gallons per acre.

Zineb.—Zineb is effective against late blight (p. 16), and it is one of the materials commonly used for control of early blight (p. 18), nailhead spot (p. 21), phoma rot (p. 24), septoria leaf spot (p. 28), leaf mold (p. 30), and gray leaf spot (p. 32). It is fairly effective against anthracnose (p. 33), but it is not equal to maneb (p. 80) or ziram (below) for control of this disease. As a spray, use 3 pounds of zineb per acre.

Zineb combined with dichlone or ferbam (p. 79) reduces losses from gray mold and other foliage diseases except bacterial spot.

Dusts containing 5 to 6 percent of zineb may be used for tomato-disease control. Spraying, however, is likely to give more satisfactory results.

Ziram.—Ziram gives good control of anthracnose (p. 33) and also is effective against leaf mold (p. 30). Apply 3 pounds of ziram to the acre. Ziram does not control late blight (p. 16). If it is used where late blight is likely to occur, apply in alternate applications with a fixed copper fungicide, zineb, or nabam or in tank-mix formulations with a fixed copper or maneb. When used with a fixed copper compound, use 1 pound of ziram and 2 pounds of a 50-percent fixed copper per acre. In some of the Central States ½ pound of powdered skim milk is added to the mixture. When combined with maneb, use 1½ pounds of ziram and 1½ pounds of maneb per acre. Or use ziram early in the season and replace it by a fixed copper compound when late blight threatens to appear.

Although spraying is preferable to dusting, dusts containing 7 to 10 percent of ziram may be used on tomatoes.

Other chemicals.—A preparation of a fixed copper combined with streptomycin (Agri-mycin 500) controls bacterial spot in seedbeds. Use 5 pounds to 100 gallons of water. This gives a concentration of 4 pounds of a fixed copper (53 percent) and 100 parts per million of streptomycin. If desired, increase the streptomycin content to 200 parts per million by adding the necessary amount of some formulation of streptomycin, such as Agri-strep, Phytomycin, or Agri-mycin 100. Apply at the rate of 100 to 150 gallons per acre.

***Caution:* Do not apply streptomycin after the fruit begins to form.**

Z,4-dichloro-6-(o-chloroamilino)-S-triazine (Dyrene) has been effective against gray leaf spot in tests in Florida. However, it does not give good control of late blight. Use as directed on the package. Apply 150 gallons per acre.

Captan has shown especial promise in control of buckeye rot, but where late blight and some other diseases are prevalent it is not recommended to the exclusion of the maneb and fixed copper compound combination (p. 80). Use as directed on the package. Apply 150 gallons per acre.

IDENTIFICATION OF TOMATO DISEASES

A key has been prepared to aid in distinguishing tomato diseases found in the field and the greenhouse. After a preliminary identi-

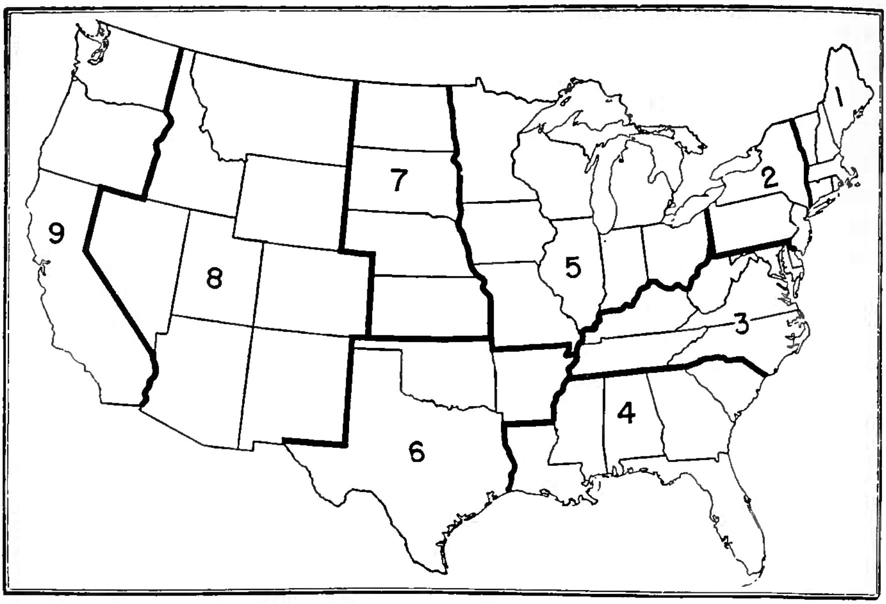

FIGURE 52.—Map of the United States showing tomato-growing regions to which the numbers in the key refer.

fication has been made with the key, the more complete description of the disease, together with the measures recommended for its control, can be consulted on the page indicated. The brief descriptions in the key are usually followed by numbers in parentheses, which refer to groups of States indicated by the same numbers on the map (fig. 52). These numbers indicate the regions where the disease often causes serious losses or occasional losses of minor importance. Many diseases, however, are occasionally found in States not included in the list of regions given in the key. If general, the letter G indicates that the disease in question may occur on tomatoes wherever they are grown in the greenhouse. However, certain greenhouse diseases are as yet somewhat localized in occurrence.

A Key to Tomato Diseases

DISEASES AFFECTING LEAVES AND STEMS, WITH OR WITHOUT SYMPTOMS ON FRUITS

A. *Diseases characterized by wilting of plant, without definite leaf spots; with or without spotting or decay of fruits.*

(a) Yellowing, wilting, and death of leaves from the base upward, followed by wilting and usually by gradual death of plant. Single shoots often killed before serious infection of others. Dark-brown discoloration of woody tissues next to the green outer cortex of stem. No soft decay of stem. No spotting of fruits, but sometimes discoloration of their water-conducting vessels. (2, 3, 4, 5, 6, 7, 8, 9, G.) ________________ **Fusarium wilt** (p. 2).

(b) Yellowing, wilting, and loss of foliage, confined largely to bases of shoots. Slight wilting of plants during day. All branches uniformly affected. Plants stunted but usually live throughout the season. Discoloration of woody tissues of stem, generally confined to lower part. No soft decay of stem and no spotting of fruits. (1, 2, 8, 9, G.)----**Verticillium wilt** (p. 5).

(c) Rapid wilting of entire plant without yellowing of leaves. Dark water-soaked decay of center of stem just above ground line, followed by death of plant. No spotting of fruits. (2, 3, 4, 5, 6.)------**Bacterial wilt** (p. 6).

(d) Wilting and upward rolling of margins of leaflets; usually only one side of leaf affected at first. Leaves browning, withering, and dying but remaining attached to stem. Dying of leaves progressing up the stem; one side of the plant often attacked first. Stems with open cankers and yellowish, mealy decay of inner tissues. Bird's-eye spotting of fruits; spots ⅛ to ¼ inch in diameter; small cavities in central portions of fruits. (Occasional wherever tomatoes are grown.)------------------**Bacterial canker** (p. 8).

(e) Gradual drooping and eventual dying of leaves over entire plant without marked yellowing of foliage. Stem decayed at ground line and covered with whitish fungus growth, with small, light-brown sclerotia. Fruits on the ground sometimes destroyed by the fungus. (3, 4, 6.)------------------------------------**Southern blight** (p. 12).

(f) Slow wilting and eventual death of plant; soft tissues of the stem decayed, with cavities that contain a grayish-white fungus growth and large, black sclerotia. Fruits commonly developing watery soft rot. (4, 6. G.)--**Stem rot** (p. 13).

(g) Emergence failure or collapse and wilting of seedling plants caused by decay of stem at ground line or of roots. (Wherever seedlings are grown.)--------------------------------------**Damping-off** (p. 15).

B. Diseases characterized by leaf spots but no wilting of plant; with little or no spotting of fruits.

(a) Numerous small, roughly circular spots 1/16 to ⅛ inch in diameter, with dark margins and gray centers dotted with minute dark specks on older leaves. Plants often seriously defoliated and fruits exposed to sun. (1, 2, 3, 4, 5, 6, 7.)--------------------------------**Septoria leaf spot** (p. 28).

(b) Large, yellowed patches on upper surfaces of older leaves; olive-brown, velvety coating of the fungus on undersurfaces of these spots. Much of foliage killed. Fruits rarely infected. (Most serious in greenhouse, but occasionally so in field; 2, 3, 4, 5, 6, G.)-----------------**Leaf mold** (p. 30).

(c) Numerous small, dark-brown spots extending through the leaf; spots may enlarge to ⅛ inch with centers becoming grayish brown with a glazed appearance. Yellowing, withering, and dropping of severely spotted leaves. Seedlings severely injured; large plants sometimes losing much of their foliage. (2, 3, 4, 5, 6.)---------------------------**Gray leaf spot** (p. 32).

C. Diseases characterized by leaf spots but no wilting of plant; with spotting or decay of fruits.

(a) Greenish-black, water-soaked patches on older leaves, increasing in size rapidly and sometimes killing much of the foliage. Water-soaked spots on fruits; spots enlarging rapidly and sometimes covering half the surface. Spots becoming brown with a firm, corrugated surface and margin more definite than in buckeye rot. (1, 2, 3, 4, 5, 6, 9, G.)------**Late blight** (p. 16).

(b) Rather large (¼ to ½ inch in diameter), dead spots on older leaves; spots brown with concentric rings. Plants partially defoliated. Circular to elongate, dark spots with light centers on stems. Partial girdling of seedling stems at ground line. Fruits developing large, dark, leathery spots near stem ends, with dark, dry decay of flesh beneath, extending to some depth. (1, 2, 3, 4, 5, 6, 7, 9.)------------------------**Early blight** (p. 18).

(c) Leaf and stem symptoms almost identical with those of early blight. Small, slightly sunken spots with dark margins and roughened, grayish-brown centers on fruits. Spots 1/16 to ⅜ inch in diameter, occurring at any point on fruits. Decay not extending deeply into fruit. (3, 4, 6.)------------------------------------**Nailhead spot** (p. 21).

(d) Dense gray fungus growth on dead leaves at base of plant. Tan or gray spots on actively growing leaves; spots become covered with gray fungus growth; leaves wither. Fruits showing water-soaked spots ¾ to 1 inch in diameter; fungus growth on surface of fruits; often soft decay of entire fruit. (4, G.) ---------- **Gray mold** (p. 22).

(e) Many small, irregular, dark spots, enlarging and developing concentric markings similar to those of early blight, on leaves. Spots often coalescing and leaves sometimes shriveling. Dark-brown, elongated spots with faint, zonate markings on stem. Seedlings sometimes severely damaged. Small (⅛-inch), depressed brown spots near stem scars on fruits in field. Depressed water-soaked spots on fruits ripening after shipment; spots enlarging to ½ to 1½ inches and becoming black and leathery and dotted with minute pustules. (3, 4, 6.) ---------- **Phoma rot** (p. 24).

(f) Small, dark, irregular, greasy-appearing spots on leaves, about ⅛ inch in diameter and often tearing out. Defoliation sometimes serious. Spotting of green fruits only: small, raised, water-soaked spots, later becoming slightly sunken and light brown, with scabby, roughened surface. Spots ⅛ to ¼ inch in diameter, not extending deeply into fruit. (2, 3, 4, 5, 6, 7.) ---------- **Bacterial spot** (p. 26).

(g) Numerous minute, dark spots on leaves extending to lower surface. Fruit symptoms most noticeable, consisting of very small, dark-brown, slightly raised specks less than 1/16 inch in diameter, scattered thickly over surface. Sometimes occurring with bacterial spot. (2, 3, 4, 5, 6, 7.) ---------- **Bacterial speck** (p. 27).

(h) Green mottling of leaves accompanied by numerous small, grayish-brown, papery spots; withering and drying of some leaves in early stages of disease. Later growth mottled green and yellow with small, irregular chocolate-brown spots. Dark-brown narrow streaks of various lengths on stems. Brown, irregular, greasy-appearing surface spots ⅛ to ⅜ inch in diameter on fruits. (Occasional wherever tomatoes are grown, but most serious in greenhouse.) ---------- **Double-virus streak** (p. 41).

(i) Small, irregular, dark-brown lesions or linear "oak leaf" markings on leaves, under some conditions. Later leaf growth often showing only green mottling. Stem sometimes showing broad, brown streaks of considerable length and brown, shriveled areas in pith. Fruits not mottled but sometimes marked with depressed, brown rings about ½ inch in diameter. (Not common in field, but occasionally serious in greenhouse.) ---------- **Single-virus streak** (p. 43).

(j) Numerous small, dark, circular spots on young leaves; such leaves sometimes have a peculiar bronzed appearance and turn dark and wither. Tips of young plants showing dark streaks and sometimes killed. New growths sometimes much stunted. Spots about ½ inch in diameter, marked with concentric, circular bands of red and yellow, on ripe fruits. Centers of spots often raised; fruits with a rough appearance. (2, 3, 5, 9, G.) ---------- **Spotted wilt** (p. 47).

D. *Diseases characterized by mottling, yellowing, curling, or malformation of leaflets and usually by more or less stunting of plant; with or without symptoms on fruits.*

(a) Green or yellow mottling of leaves; some curling, malformation, and dwarfing of leaflets. Plants slightly stunted. Fruits mottled by yellow strains of virus. (Wherever tomatoes are grown.) ---------- **Tobacco mosaic** (p. 37).

(b) Pronounced stunting and bushy growth of plant. Mild, green mottle of leaflets accompanied by marked filiform malformation ("shoestring"). Only a few small fruits produced. (Occasional wherever tomatoes are grown.) ---------- **Cucumber mosaic** (p. 44).

(c) Dark-brown dead spots on nearly mature leaflets. Veins of young leaflets banded with yellow. Leaves of later growth faintly mottled, slightly distorted, and curled downward. Purplish streaking of stem. Plants stunted. (Chiefly Florida.) ---------- **Potato-Y virus** (p. 46).

(d) Plants yellowed and stunted, with abnormally erect stems. Upward rolling of leaflets exposing the undersurface. Veins purple and leaves stiff and leathery. Petioles curved downward and leaflets twisted. Many roots and rootlets killed and plants often dying. Few or no fruits produced after infection. (6, 7, 8, 9.) ---------- **Curly top** (p. 49).

(e) Older leaflets thickened and rolled upward at base. Leaflets yellowish green with purple veins and margins. Young leaves narrow, dwarfed, and curled upward at tip. Sometimes abnormally numerous blossoms; fruits yellowish red and soft. Symptoms somewhat like those of curly top, but disease developing more slowly and plants not rapidly killed. (7, 8, 9.)---------- **Psyllid yellows** (p. 52).

(f) Plants dwarfed, sickly, and sometimes wilting readily in dry weather; frequently killed. Swellings, or galls, on roots. (Occasional wherever tomatoes are grown; common in 3, 4, 6, 8, 9, G.)---------- **Root knot** (p. 55).

(g) Leaflets of older leaves rolling upward and inward at margins; no yellowing or dwarfing of leaflets. Little or no stunting of plants. Fruits of normal size and color. (Occasional wherever tomatoes are grown.)---------- **Leaf roll** (p. 62).

(h) Downward curvature of leaves and growing points of stems. Young leaflets distorted—twisted at margins and abnormally pointed at tips. Veins light colored and appear parallel. Tissue between veins often raised in wartlike protuberances. Main stem developing small, aerial roots and sometimes splitting. "Catface" deformity of fruits; few, if any, seeds produced. (Wherever tomatoes are grown.)---------- **2,4-D injury** (p. 63).

DISEASES AFFECTING ONLY THE FRUITS[5]

A. Diseases characterized by rot of the fruit.

(a) Slightly sunken water-soaked, circular spots on ripe fruits; spots becoming darker than the surrounding tissue. Older spots about ½ inch in diameter and with concentric markings. Centers sometimes tan, with dark specks; in wet weather often salmon colored by masses of spores. (Infection occasionally causes slight spotting on leaves near soil.) (2, 3, 5, 6, 7.)---------- **Anthracnose** (p. 33).

(b) Grayish-green or brown, water-soaked spots with smooth margins, often covering half of fruit surface; most common on fruit in contact with soil. Spots commonly have broad concentric bands of darker brown. (1, 2, 3, 4, 5, 6, 9, G.)---------- **Buckeye rot** (p. 34).

(c) Sunken brown spots ¾ to 1¼ inches in diameter, with narrow, dark concentric markings on fruits in contact with or near soil. Spots smaller and zonate bands narrower than those in buckeye rot. Centers of spots sometimes breaking open. (Wherever tomatoes are grown in the field.)---------- **Soil rot** (p. 35).

(d) Rots occurring chiefly on fruits with mechanical injuries, growth cracks, insect punctures, spotting due to other diseases, or any other injury to epidermis. Often accompanied by odor of fermentation. (Wherever tomatoes are grown.)---------- **Minor fruit rots** (p. 36).

(e) Shrinking of tissues at blossom end of fruit, causing a dark, flattened or sunken, leathery-appearing spot, sometimes including half of fruit. (Wherever tomatoes are grown.)---------- **Blossom-end rot** (p. 57).

B. Diseases characterized by cracking, spotting, blotching, or malformation of fruits, but by no rot except from secondary infections by decay-producing organisms.

(a) Shoulders of fruits somewhat flattened; grayish-brown, slightly depressed blotches on fruit surface. Dark-brown discoloration of tissues of walls and septa of fruits. (Wherever tomatoes are grown.)---------- **Internal browning** (p. 40), **Graywall** (p. 58).

(b) Fruits slightly flattened at sides, soft, and light in weight. Large cavity between outer wall and center of fruit. (Wherever tomatoes are grown; frequent occurrence: 4, 6, 9, G.)---------- **Pockets** (p. 59).

(c) Large yellow or whitish patches on parts of fruits exposed to sun. Spots remaining firm or shrinking and forming pale, flattened areas with grayish-white papery surface. (Wherever tomatoes are grown in the field.)---------- **Sunscald** (p. 60).

(d) Cracking of fruits at stem ends, extending either radially or longitudinally. Cracks generally healing. (Wherever tomatoes are grown.)---------- **Growth cracks** (p. 61).

(e) Fruits deformed and with swollen protuberances at blossom ends. Masses of scar tissue between swellings; sometimes cavities extending into fruits. (Wherever tomatoes are grown.)---------- **Catface** (p. 62).

(f) Irregular whitish to yellow spots $\frac{1}{16}$ to ½ inch in diameter, just below epidermis of fruit. Spots showing glistening white masses of cells upon removal of skin. (1, 2, 3, 4, 5, 6.)---------- **Cloudy spot** (p. 54).

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[5] Except for anthracnose, which see.

(g) Small, shallow, roughened pits scattered over fruit, often massed and forming streaks extending from shoulder to blossom end. No rot. (4, 5, 6, 9.) ---------- **Fruit pox** (p. 65).

(h) Whitish rings about ⅛ to 3/16 inch in diameter scattered over surface of fruit. (Occasional.) ---------- **Ghost spot** (p. 23).

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